Research Studies Related to Snowmobiling Impacts

Compiled by Trails Work Consulting
For the American Council of Snowmobile Associations

2021 Update

Research Studies Related to Snowmobiling Impacts

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ACKNOWLEDGEMENTS AND DISCLAIMER

This compilation of research studies has been produced to help further snowmobiling access and management with financial assistance from the Recreational Trails Program administered by the U.S. Federal Highway Administration (FHWA). It represents an update and expansion of Appendix 8 in the *Access Guide for Snowmobiling on Private and Public Lands*, originally produced in 2008 by the American Council of Snowmobile Associations with financial assistance from FHWA.

The purpose of this publication is educational only; with no other intent but to expand the knowledge base of snowmobile trail developers and managers to assist with providing snowmobiling access. It should not be assumed by readers that all contributors agree with every written word, but are opinions only. The authors, contributors, FHWA, Trails Work Consulting, and ACSA and its members accept no liability resulting from the compliance or noncompliance with the procedures or recommendations given herein, or for the accuracy or completeness of the information contained herein.

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INTRODUCTION

Landowners and public land managers may deny access if they believe recreational use will adversely impact the ecology of their lands or negatively affect other uses of properties they control. All recreational trail activities – whether hiking, biking, snowmobiling, skiing, ATV, motorcycle or horseback riding – can potentially create environmental or social impacts. Understanding exactly what those potential impacts may be is vital to successfully obtaining and retaining access; consequently trail providers must recognize this up-front and actively manage to mitigate or eliminate potential impacts.

This compilation provides an extensive list of summaries and web links from a wide range of impact studies related to snowmobiling. This information is an important tool to help assist trail providers in negotiations for new or continued access. Whether old or new, these studies have relevance to present day discussions about snowmobiling access. While not every study applies to every local situation, many can be credibly extrapolated for use where local situations are similar to a particular study's settings.

All abstracts are presented as direct cites from study authors. Information is organized alphabetically by impact topic, and then listed from the most recent to the oldest studies with key findings highlighted. Important perspectives can be gained by following the progression of knowledge forward in time as impact topics gain perspective with new research that either dispels myths or better defines real impacts.

This compilation represents the 'best available information' about snowmobiling impacts. Public land managers often use 'best available information' as their standard for analysis of impacts, particularly when local data are not available. Consequently this information should be shared and used to help land managers make informed decisions about snowmobiling access.

History of Snowmobiling Related Research
A large number of snowmobiling studies date back to the 1970s and 1980s – when snowmobiling was fairly new, growing rapidly in popularity, and concerns by land managers and citizens about this new winter activity were high. This early research often disproved concerns, showed snowmobiling impacts were far less than had been feared, or concluded additional research was needed to more fully analyze theories about alleged issues. As positive answers were found, the focus of recreation impact research gradually turned away from snowmobiling to other activities deemed to be higher priority concerns.

Interest in snowmobile impacts resurfaced in the late 1990s and early 2000s when public debate flared over continued snowmobile access to Yellowstone National Park. With snowmobiling under an intense spotlight, numerous new snowmobile studies were conducted through a series of winter use environmental impact statements and on-going monitoring of snowmobile use. While snowmobiling in Yellowstone is quite different from most other snowmobiling areas, new Yellowstone information is nonetheless useful for informed inferences about potential impacts elsewhere.

While the rapid growth of ATV use in recent years also generated new ATV/OHV impact studies, this compilation focuses solely on snowmobiling – except for a few examples where OHV-related deer studies reached similar conclusions as what snowmobile-deer research had decades earlier. Consequently – even though ATVs and snowmobiles have distinctly different operational characteristics – some aspects of their use are similar enough to sometimes make informed inferences about some topics.

SNOWMOBILING IMPACT TOPICS

AIR QUALITY / EMISSIONS

1. **Comparability Assessment of Snowmobile and Snowcoach Transportation Event Impacts to Park Resources and Values and the Visitor Experience.** Yellowstone National Park Winter Use Plan – Supplemental Environmental Impact Statement, Appendix A **(**February 2013) National Park Service
https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

Executive Summary: This appendix was prepared in response to requests made during the public comment period on the Draft Winter Use Plan / Supplemental Environmental Impact Statement (plan/SEIS) that a stand-alone section of the final plan/SEIS be dedicated to discussing the comparability of snowmobile and snowcoach transportation events in terms of their relative impacts to park resources and values and visitor experience.

A transportation event is defined as one best available technology (BAT) snowcoach or a group of seven to ten New BAT snowmobiles traveling together through the park.

The purpose of this appendix is to assess the comparability of transportation event impacts to park resources and values and the visitor experience for the following five impact topics: (1) Wildlife and Wildlife Habitat, including Rare, Unique, Threatened, or Endangered Species, and Species of Concern, (2) Air Quality, (3) Soundscapes and the Acoustic Experience, (4) Visitor Use, Experience, and Accessibility, and (5) Health and Safety. Given best available data, for each of these impact topics it was feasible to meaningfully assess comparability of the two types of transportation events at either the "per person" or "per transportation event" levels for one or more metrics. The existing data did not permit meaningful assessment of comparability for impact topics Socioeconomic Values and Park Operations and Management. These impact topics are reviewed in-depth in chapter 4 of the plan/SEIS.

By "comparable," the National Park Service (NPS) explains how the impacts from the two types of transportation events are relatively close to one another and that neither mode of transportation consistently results in less adverse impacts to park resources and values or provides a more beneficial visitor experience. The NPS does not state the two types of oversnow vehicle (OSV) transportation are *equivalent*; rather, the comparability analysis reveals that:

- One mode of transportation is not conclusively cleaner, quieter, or less harmful to wildlife than the other;
- One mode of transportation does not provide for higher quality visitor experiences than the other;
- One mode of transportation is not conclusively more harmful to health and safety of visitors and employees than the other; and
- At the levels prescribed under the preferred alternative, neither form of oversnow transportation will result in a level of adverse impacts on park resources that would necessitate an outright ban on that type of transportation.

Due to the unique situation in Yellowstone in winter, whenever possible the analyses rely on monitoring and modeling data from peer-reviewed publications and technical reports specific to Yellowstone, and are limited to the "managed use" era (December 2004 through present).

For Wildlife and Wildlife Habitat, Including Rare, Unique, Threatened, or Endangered Species, and Species of Concern:

- White et al. (2009) found that probabilities of movement were greater for bison exposed to snowcoaches than for those exposed to snowmobiles; "the odds of observing a movement response were 1.1 times greater for each additional snowmobile, 1.5 times greater for each additional coach" (p. 587).
- For bison, there are mixed results in terms of percentage of "active" movement responses generated by the two different types of events. In 2006/2007, snowmobiles caused an "active" movement response 3.1 percent of the time verse snowcoaches which caused an "active" movement response 0.7 percent of the time. In 2008, snowmobiles caused an "active" movement response 8 percent of the time to snowcoaches 8.8 percent. In 2009, the percentages were almost event (3.5 percent to 3.5 percent, snowmobiles to snowcoaches).
- For elk, during the winter seasons of 2006/2007 and 2008/2009, no "active" behavioral response (travel, alarm-attention, or flight) was observed from either snowmobile or snowcoach transportation events. During the winter season of 2007/2008, snowmobile transportation events caused an "active" behavioral response 11.4 percent of the time and snowcoaches caused an "active" behavioral response 20.5 percent of the time.
- For trumpeter swans, the results are mixed in terms of percentage of "active" movement responses caused by the two different types of transportation events. For the three years of reporting summarized in this appendix, snowmobiles caused an "active" movement response 3.4 to 4.8 percent of the time while snowcoaches caused swans to exhibit an "active" movement response zero to 13.8 percent of the time.
- The best available evidence strongly indicates that OSV use during the managed use era has had no discernible effect on population dynamics or distribution for the five species (bison, elk, trumpeter swans, wolves, and bald eagles) that have been studied extensively and that other ecosystem stressors, not OSV use, are dominant influences on these wildlife species.

For Air Quality:

- Snowmobile transportation events and snowcoach transportation events both offer some benefits and some drawbacks relative to each other in terms of tailpipe emissions and that there is no universally "cleaner" (less polluting) mode of oversnow transportation.
- During a representative roundtrip from West Yellowstone to Old Faithful, a New BAT snowmobile transportation event produces less carbon monoxide (CO) than a BAT snowcoach event. However, a BAT snowcoach transportation event produces considerably less hydrocarbons (HC) and nitrogen oxides (NO_x) than a New BAT snowmobile transportation event during the same representative roundtrip.
- At the SEIS alternative level, SEIS alternatives 4a–4d are as clean as or cleaner than the other two SEIS alternatives (2b and 3b) at the "per person" level for a maximum use day.

For Soundscapes and the Acoustic Experience:

- Across 10 sites, snowcoach transportation events were audible for, on average, 2 minutes and 21 seconds (2:21) and snowmobile transportation events were audible, on average, for 2 minutes and 36 seconds (2:36), a difference of, on average, 15 seconds.
- When measured at 50 feet at cruising speed, a group of ten New BAT snowmobiles (each producing 67 dBA), measure 3 dBA lower than a single BAT snowcoach at cruising speed (approximately half of the noise energy). The two types of transportation events would have similar noise energy levels at more distant locations.

- At a distance, if vehicles are not visible, trained acousticians, as well as people with less experience, typically cannot differentiate between the noise produced by snowmobile and snowcoach transportation events.
- Once BAT is in place for snowcoaches and New BAT in place for snowmobiles, there is no evidence to support a compelling advantage for one type of OSV transportation event over another in terms of preservation of the natural soundscape.

For Visitor Use, Experience, and Accessibility:

- Visitors, regardless of their chosen mode of transportation, are highly satisfied with their overall experience.
- Given established OSV travel patterns and routes, visitors have comparable opportunities to experience wildlife and other features of interest and to experience natural soundscapes, whether they are on a snowmobile or riding in a snowcoach.

For Health and Safety:

- Employee and visitor exposure levels to air pollutants and elevated noise produced by OSVs do not exceed U.S. Environmental Protection Agency (EPA), Occupational Safety and Health Administration (OSHA) or National Institute for Occupational Safety and Health (NIOSH) standards.
- On February 15, 2009, at the West Entrance, snowcoaches were separated from snowmobiles into two different lanes to determine if employee exposure levels to CO varied by transportation event type. CO readings were slightly higher over the sampling period in the snowmobile lane; however, peak readings for CO were higher in the snowcoach lane. Neither lane reached the NIOSH ceiling of 200 ppm in either entrance lane.

For many of the topics evaluated, the environmental impacts were similar and for other topics the impacts are different. However, in summary for the five impact topics for which assessing comparability at the person or event levels was possible, data indicates that impacts for both modes of transportation are low and that no one mode of transportation is clearly better, in terms of limiting environmental impacts and providing high quality visitor experiences, than the other.

2. **Yellowstone Over-snow Vehicle Emission Tests – 2012: Preliminary Report.** Ray, J.D., Bishop, G., Schuchmann, B., Frey, C., Sandu, G., & Graver, B. (2012) National Park Service Air Resources Division, University of Denver – Chemistry Department and North Carolina State University – Department of Civil Engineering. http://www.nps.gov/yell/parkmgmt/upload/pem_of_snowcoaches-snowmobiles_3-2012.pdf

Abstract/Executive Summary: This is a preliminary report to provide summary tables for the EIS scenario modeling. Emission data from newer model snowcoaches and snowmobiles were obtained by direct tailpipe measurements and are now available for modeling. A comparison is made with prior data and summary values for different categories are provided that can be used in the modeling. Fleet averages are calculated based on snowcoach categories and the estimated number of vehicles in each category. The full report will include more detail on vehicles tested, experimental methods, detailed results, and perspective on the findings.

Conclusion: New emission data are now available for newer models of snowmobiles and recent additions to the snowcoach fleet. Emissions are generally lower for newer snowcoaches compared to mean values of the earlier fleet and especially compared to the older carbureted engine snowcoaches.

It is less clear that the model year 2011 snowmobiles are meeting desired emissions objectives. Emissions are higher than from previous models. Because our sample size is very small, it would be best to have some additional measurements. The manufacturers' fleet data supports the increase in emissions.

Emissions data are now available for the modeling exercise. Table 9 and 10 put the different snowcoaches into categories according to their emissions, fuel type, and engine configuration. The overall "fleet" is a mixture of these different types. The current fleet is the snowcoaches that the rental shops use most. That actual mix may not be known, but is estimated from an inventory of all snowcoaches in use. The future fleet is the snowcoaches allowed under a new snowcoach BAT policy and whatever new vehicles are added as replacements.

3. **Winter air quality in Yellowstone National Park: 2009–2011.** Ray, J. D. (2011) Natural Resource Technical Report NPS/NRSS/ARD/NRTR—2012/551. National Park Service, Denver, CO. http://www.nps.gov/yell/parkmgmt/upload/2009-2011_yell_winteraq.pdf

Executive Summary: The air quality in Yellowstone National Park was monitored at two locations within the park and at a location near the center of West Yellowstone city as part of the adaptive management program on the use of over-snow winter motor vehicles. The leading indicators used were ambient concentrations of carbon monoxide (CO) and particulate matter of 2.5 micrometers or less (PM2.5). New measurements of nitrogen oxides (NOx) have been added at the West Entrance station.

The monitoring data from West Entrance near the town of West Yellowstone, MT, is used to characterize for overall air quality and its relationship to traffic, because of its longer record and detailed traffic counts. Old Faithful is a destination for most of the winter use vehicles and another congestion point; CO and PM2.5 concentrations are lower at Old Faithful than at the West Entrance. CO and PM2.5 are also monitored outside the park in the city of West Yellowstone, MT in cooperation with the Montana Department of Environmental Quality (MT DEQ); summary data from the urbanized area are reported here for comparison.
This report updates prior air quality and emission reports. Prior reports (http://www.nature.nps.gov/air/studies/yell/yellAQwinter.cfm) provide monitoring and instrument details and background information.

The notable findings for this two year period are:

- Hourly and 8-hour concentrations of CO are at low at the West Entrance and have repeated in the same range for the last 3-7 years; at Old Faithful, concentrations are slightly lower than at the West Entrance.
- Air quality at Yellowstone meets the national standards set by the Environmental Protection Agency (EPA) for CO and PM2.5 to protect human health. The CO, however, is present above regional background concentrations (between 0.1 and 0.2 ppm) in areas near vehicle routes, especially during the winter.
- Daily average concentrations of PM2.5 continue to decrease in the park while measurements of PM2.5 within the city of West Yellowstone are the same or higher than previous winters. PM2.5 concentrations in the City of West Yellowstone do not violate the national standard.
- At current vehicle emission levels from over-snow vehicle (OSV) traffic, the majority of PM2.5 concentrations appear to be coming from non-park traffic sources at the West Entrance and at Old Faithful.
- Nitrogen dioxide (NO2) concentrations road-side at the West Entrance are a larger percentage of the new 1-hour health standard for NO2 than CO or PM2.5 are for their standards. Although the NO2 concentrations are of concern, the NO2 is below the standard.

4. **Winter air quality in Yellowstone National Park: 2007—2008.** Ray, J. D. (2008) Natural Resource Technical Report NPS/NRPC/ARD/NRTR—2008/139. National Park Service, Fort Collins, CO. http://www.nps.gov/yell/parkmgmt/upload/aq70-08__final.pdf

Executive Summary: The air quality in Yellowstone National Park was monitored at two locations as part of the adaptive management program on the use of over-snow winter motor vehicles. The leading indicators used were ambient concentrations of carbon monoxide (CO) and particulate matter of 2.5 micrometers or less (PM2.5).

The West Entrance near the town of West Yellowstone, MT, is the primary indicator for overall air quality and the relationship to traffic, because detailed entry counts could be obtained at that site. Old Faithful is a destination for most of the winter use vehicles; CO and PM2.5 concentrations are lower at Old Faithful than at the West Entrance.

This report is an update to prior air quality and emission studies. The notable findings this year are:

- Maximum hourly concentrations of CO and PM2.5 are up slightly at the West Entrance, but are nearly the same as last year at Old Faithful.
- Air quality at Yellowstone meets the national standards set by the Environmental Protection Agency (EPA) for CO and PM2.5 to protect human health. The CO air pollutant, however, is present above natural regional background concentrations (between 0.1 and 0.2 ppm) in areas near vehicle routes, especially during the winter.
- There is a high degree of uncertainty in changes associated with winter traffic at the West Entrance or Old Faithful to any differences in measured air quality during the winter 2007-2008 season. Weather and traffic density are important factors to explain the daily and hourly variations in ambient air pollutant concentrations.

5. **Air quality at a snowmobile staging area and snow chemistry on and off trail in a Rocky Mountain subalpine forest, Snowy Range, Wyoming.** Musselman, R.C. & Korfmacher, J.L. (2007). USDA Forest Service Region 2 Rocky Mountain Research Station, Fort Collins, CO. http://www.fs.fed.us/rm/boise/AWAE/scientists/profiles/Musselman/Musselman%20Korfmacher%20Snowmobile%20EM&A2007.pdf

Abstract and Conclusions: A study was begun in the winter of 2000–2001 and continued through the winter of 2001–2002 to examine air quality at the Green Rock snowmobile staging area at 2,985 m elevation in the Snowy Range of Wyoming. The study was designed to evaluate the effects of winter recreation snowmobile activity on air quality at this high elevation site by measuring levels of nitrogen oxides (NOx, NO), carbon monoxide (CO), ozone (O3) and particulate matter (PM10 mass). Snowmobile numbers were higher weekends than weekdays, but numbers were difficult to quantify with an infrared sensor. Nitrogen oxides and carbon monoxide were significantly higher weekends than weekdays. Ozone and particulate matter were not significantly different during the weekend compared to weekdays. Air quality data during the summer was also compared to the winter data. Carbon monoxide levels at the site were significantly higher during the winter than during the summer. Nitrogen oxides and particulates were significantly higher during the summer compared to winter. Nevertheless, air pollutants were well dispersed and diluted by strong winds common at the site, and it appears that snowmobile emissions did not have a significant impact on air quality at this high elevation ecosystem. Pollutant concentrations were generally low both winter and summer. In a separate study, water chemistry and snow density were measured from snow samples collected on and adjacent to a snowmobile trail. Snow on the trail was significantly denser and significantly more acidic with significantly higher concentrations of sodium, ammonium, calcium, magnesium, fluoride, and sulfate than in snow off the trail. Snowmobile activity had no effect on nitrate levels in snow.

Specific conclusions of this study include: 1) It was evident that more snowmobiles were present at the site weekends than weekdays, but the infrared counter proved inadequate for providing accurate snowmobiles counts. (2) There were significant differences in air quality between weekends and weekdays. Data show significantly higher concentrations on weekends in winter when more snowmobiles were present for CO, NO2, NO, and NOx, but not for O3. Concentrations of CO and NO were also higher weekends than weekdays during summer. Mean daily maxima of NO, NO2, and NOx occurred weekends during the winter. The data suggest that although NOx concentrations were generally low, increased weekend concentrations resulted from snowmobile activity. (3) Seasonal differences were evident in air chemistry, specifically for CO, NO2, and NOx, but not for NO or O3. NO2 and NOx were higher in summer than winter, while CO concentrations were higher in winter than summer. Nevertheless, air pollutant concentrations were generally low both winter and summer, and were considerably lower than exceedence levels of NAAQS. (4) PM10 was lower in winter than summer, and there were no significant weekend/weekday differences. (5) CO and O3 concentrations were higher, and NOx and NO2 were lower, when the wind was from the south. The monitoring was conducted just north of the roadway. O3 was lower and NO2 and NOx were higher when wind velocities were lower. The data suggest that under prevailing wind conditions air pollutant concentrations on the roadway were likely higher than those detected by our monitoring sensors. Nevertheless, an air pollution signal was detected that could be related to snowmobile activity; but the pollutant concentrations were low and not likely to cause significant air quality impacts even at this high snowmobile activity site. (6) Wind speed and physical site characteristics are probably the most important determinants of pollutant concentrations at the level of use described in most existing studies of snowmobile pollutants. There was greater dispersion of pollutants with high winds The open, high elevation Snowy Range site with high winds may be much less likely to experience pollutant levels at or near exceedence criteria than a (relatively) low-altitude site with somewhat restricted terrain and low wind speeds, (e.g., West Yellowstone). (7) Snow chemistry was significantly different between on and off trail for some analytes when sampling was designed to collect from areas with or without snowmobile activity. Na+, Ca2+, Mg2+, NHþ4, F− and SO2_ 4 appeared to be higher on the trail than off, especially early in the season. The trail followed a roadway, which may have affected on-trail snow chemistry concentrations. There were no differences in NO_3 on or off the trail. Snow density was higher on the trail than off.

6. **Winter Air Quality in Yellowstone National Park: 2006 – 2007.** Ray, J. D. (2007) Natural Resource Technical Report NPS/NRPC/ARD/NRTR--2007/065. National Park Service, Fort Collins, CO. http://www.nps.gov/yell/parkmgmt/upload/winteraq06-07_final.pdf

Abstract: Air quality monitoring for carbon monoxide (CO), particulate matter (PM2.5), and meteorological parameters was conducted during the winter of 2006-2007 in Yellowstone National Park at two busy traffic locations. Data from a West Yellowstone monitor and from other seasons at the two in-park monitors were also compared. The CO and PM2.5 concentrations are nearly the same as the previous two winter seasons and considerably lower than before the implementation of winter vehicle restrictions. Winter CO concentrations remain higher than the summer CO concentrations when there is much more traffic. PM2.5 concentrations are now higher during the summer because of the reduced snowmobile particulate emissions in winter and the frequent incidence of smoke during the summer that is unrelated to vehicle traffic. The restrictions on winter vehicle traffic imposed by the Temporary Winter Use Plan have been effective in bring down air pollution concentrations from values approaching the National Standards to values now less than 25% of the standards. However, winter concentrations are still above the normal background concentrations expected for an isolated continental location where natural conditions should prevail.

Executive Summary: The air quality in Yellowstone National Park was monitored at two locations as part of the adaptive management program on the use of over-snow winter motor vehicles. The leading indicators used were ambient concentrations of carbon monoxide (CO) and particulate matter of 2.5 micrometers or less (PM2.5).

The West Entrance near the town of West Yellowstone, MT is the primary indicator for overall air quality and the relationship to traffic, because detailed entry counts could be obtained at that site. A new monitoring station within the town of West Yellowstone shows higher CO and PM2.5 concentrations than observed at the park entrance. Old Faithful is a destination for most of the winter use vehicles; CO and PM2.5 concentrations are lower at Old Faithful than at the West Entrance.

This report is an update to prior air quality and emission studies. The notable findings this year are:

- Air quality at both the West Entrance and Old Faithful is well below the national ambient air quality standards for human health and considered by EPA to be acceptable. The EPA standard may be too high to be a target concentration for a remote natural area park such as Yellowstone.
- The CO concentrations were about the same as previous years despite an increase in the total number of winter vehicle entries at the west entrance.
- Summer concentrations of CO at the West Entrance and Old Faithful are lower for both the average and peak values than the winter concentrations despite the larger number of vehicles in the summer.
- PM2.5 concentrations no longer appear to be correlated to winter traffic at the current traffic volumes. The much lower particulate emissions from snowmobiles with 4-stroke engines have reduced PM2.5 concentrations so that other area sources begin to dominate the observed concentrations.

7. **Portable Emission Measurements of Snowcoaches and Snowmobiles in Yellowstone National Park.** Bishop, G. A., Stadtmuller, R., Stedman, D.H. & Ray, J.D. (2007) University of Denver – Department of Chemistry and Biochemistry and National Park Service Air Resources Division. http://www.nps.gov/yell/parkmgmt/upload/YNP_2006_snowcoach_snowmobile_study.pdf

Executive Summary: The University of Denver carried out a ten day, winter emissions collection program in Yellowstone National Park that concentrated on measuring the in-use emissions from commercial snowcoaches and snowmobiles operating out of the town of West Yellowstone, MT. Between January 25 and February 3, 2006 we instrumented ten snowcoaches and two snowmobiles with a portable emissions analyzer and collected approximately 22 hours of emissions and vehicle activity data. This report and all of the data sets collected are available for download at www.feat.biochem.du.edu.

- Snowcoach carbon monoxide (CO), hydrocarbon (HC) and nitrogen dioxide (NO2) emissions from the ten coaches tested this year were 60%, 83% and 54% less than the nine coaches measured in 2005. The average age of this year's fleet was nearly 5 years newer, 9 out of 10 snowcoaches in 2006 were port fuel injected (only 4 out 9 were in 2005) and the route driven less demanding.
- When combined with the previous year's data, emission trends generally decrease with decreasing age. Carbureted engines produce more excess emissions than throttle body injected engines which produce more emissions than port fuel injected engines. Emissions continue to decrease with age among the port fuel injected engines as the newest models continue to improve on capping the extent of excess emissions during power enrichment excursions.
- As observed during last year's testing the carbureted vintage Bombardier had the highest overall emissions and a Bombardier that had been upgraded to a modern port fuel injected engine had the lowest overall emissions. However, this year's carbureted Bombardier did not exhibit the huge HC emissions that were observed previously.
- Despite driving all of the snowcoaches over the same route and with the same passenger loading large variations in CO and HC emissions were still observed. For one set of five nearly identical snowcoaches (same make, engine and track system) CO emissions varied from 310 grams/mile to 12

grams/mile and HC emissions varied from 2.4 grams/mile to 0.3 grams/mile. We believe that the large variation in readings is most likely a result of load differences produced by changes in the snow conditions.

- Passenger loading appears to be only a minor influence on the overall CO and HC emissions of a snowcoach. More important factors are snow conditions, fuel injection technology, power to weight ratio of the vehicle and the overall surface area of the track and ski system.
- We successfully instrumented two snowmobiles a 2006 Arctic Cat T660 and a 2004 Ski Doo Legend GT and drove them over the same road course as the snowcoaches. Observed emissions validated emission trends observed with the remote sensing and PEMS measurements collected in 2005. The smaller, higher revving Arctic Cat engine had lower CO emissions but higher HC and NOx emissions than the larger, lower revving Ski Doo engine. Measured fuel economies from these two snowmobiles were 25.1 and 28.3mpg, much higher than either the previous measurement or estimates used previously.
- The transient emissions behavior of these two snowmobiles is quite different with the Ski Doo snowmobile's higher CO emissions being a result of power enrichment excursions during accelerations. These higher transient emissions are probably not observed during BAT certification testing since it is a steady state test.
- Through two seasons of testing we have found that emissions variability is much greater among the snowcoach fleet where even modern coaches with advanced emissions control equipment have days with very large excess emissions. The 4-stroke snowmobiles have very high power to weight ratios and do not appear to experience these emission extremes. When comparing this years snowmobile and snowcoach PEMS measurements the 4-stroke snowmobiles had on average lower gram/mile emissions for all species and lower gram/mile/person emissions for CO and HC than the average snowcoach.

8. **Winter Air Quality in Yellowstone National Park 2005-2006.** Ray, J.D. (2007) National Park Service Air Resources Division. http://www.nps.gov/yell/parkmgmt/upload/final_05-06_air_quality_report.pdf

Executive Summary: The air quality in Yellowstone National Park was monitored at two locations as part of the adaptive management program on the use of over-snow winter motor vehicles. The leading indicators used were ambient concentrations of carbon monoxide (CO) and particulate matter of 2.5 micrometers or less (PM2.5). Emission measurements in the last two years have indicated that snowmobiles and snowcoaches may have approximately equal contributions to the concentrations of CO. Detailed entry counts of each type of vehicle at the west entrance were used in the analysis. The West Entrance near the town of West Yellowstone, MT is the primary indicator for overall air quality and the relationship to traffic, because detailed entry counts could be obtained at that site. Old Faithful is a destination for most of the winter use vehicles; they are present mid-day and that area represents the highest density of winter vehicles.

This report is an update to prior air quality and emission studies. The notable findings this year are:

- Air quality at both locations is good during the winter and is now well below the national ambient air quality standards.
- The CO concentrations were about the same as last year despite an increase in the total number of winter vehicle entries (over last year's shorter season) at the west entrance.
- Even though summer traffic volumes are nearly 60 times higher than winter traffic volumes, the highest hourly CO concentrations at both locations occur during the winter. However, the mean CO concentrations in winter have decreased over the last several years to be less than a factor of 2 higher than the summer concentrations.
- PM concentrations now correlate only weakly to traffic counts at the West Entrance and not at all at Old Faithful. This reflects lower emissions by winter vehicle although other local sources remain.

- The combination of reduced winter vehicle entries to the park and reduced emissions by the snowmobiles, using Best Available Technology (BAT), has greatly reduced the CO concentrations. Air quality has been stable or improving over the last three winters when the BAT requirement has been in effect.

Recommendations:
- Monitoring could be reduced. The particulate monitoring measures more PM2.5 from summer wildfires than from motor vehicles. The PM2.5 and meteorological measurements at Old Faithful could be reduced to just winter-time CO without compromising the adaptive management metrics.
- The question of how much CO concentrations will increase if snowmobile traffic is allowed to increase up to the winter use plan limit is unresolved. It is recommended that the monitoring at the West Entrance continue and better vehicle counting and identification methods be used.
- Efforts should continue to keep the amount of vehicle queuing at the West Entrance to a minimum and to spread out the entry of vehicles. The direct emissions testing indicates that older snowcoaches are now more polluting than BAT snowmobiles. Some effort should be made to equalize the snowcoach emissions (such as a snowcoach BAT) and to take advantage of the lower emissions that are possible as observed with newer snowcoaches or those retrofitted with new engines.

9. **In-Use Emission Measurements of Snowmobiles and Snowcoaches in Yellowstone National Park.** Bishop, G. A., Burgard, D.A., Dalton, T.T., & Stedman, D.H. (2006) University of Denver – Department of Chemistry and Biochemistry and the National Park Service. http://www.nps.gov/yell/parkmgmt/upload/bishopreport11_05.pdf

Executive Summary: The University of Denver conducted a twelve day, winter, emissions measurement program in Yellowstone National Park that involved the collection of emissions data from in-use snowcoaches and snowmobiles between February 7 and February 18, 2005. In all more than 34 hours and 500 miles of mass emissions data were collected from nine snowcoaches and more than 960 snowmobile measurements were made. This report and all of the data sets collected are available for download from www.feat.biochem.du.edu.
- Both snowcoaches and 4-stroke snowmobiles have lower emissions per person than the 2-stroke snowmobiles. 4-stroke snowmobile emissions reductions averaged 61% for CO and greater than 96% for hydrocarbons compared to 2-strokes.
- 4-stroke snowmobiles have lower emissions per person than the measured mix of snowcoaches for CO. However, newer coaches with modern pollution controls have lower per person emissions than the current 4-stroke snowmobiles.
- The reduction in 4-stroke snowmobile hydrocarbons was significant (< 96%) and readily observed. Visible exhaust plumes and odor were greatly reduced. The greater engine efficiency is reflected in an improved gas mileage by the 4-stroke snowmobiles.
- Among 4-stroke snowmobiles, the average CO emissions varied by a factor of 3 between manufacturers. The ration of CO/NO emissions varied greatly based on the engine tuning by the manufacturer.
- The Arctic Cat and Polaris 4-stroke snowmobiles emitted roughly half as much CO and HC as the Ski Doo snowmobiles. No statistically significant difference in emissions was observed by model year.
- Higher CO and HC emissions were observed from the guide snowmobiles that had been turned off and restarted at the entrance gate.
- Snowmobile emissions were NOT observed to increase with speed on a gm/mile basis. Emissions are greatest during initial startup and idling, especially when the engine is cold.
- The mean snowmobile emissions measured in the gate area appear to provide a representative average emissions value for overall park snowmobile emissions.
- The conversion vans operate often in off-cycle engine mode when much greater pollutants are emitted. The time weighted off-cycle operations for all the coaches averaged 20% of the time for the

inbound trips and 29% for outbound. This is primarily caused by the high load on the engine and underpowered coaches that causes the transmission to shift up and down. Newer vans with larger engines were found to have lower emissions.

- The Bombardier snowcoach with an uncontrolled carbureted engine had the highest CO and HC emissions and operated in this high region 98% of the time. Extremely high CO emissions were also observed at the west entrance from several additional vintage Bombardiers. Vans and coaches with efficient fuel-injected engines and catalytic converters can be nearly as clean as modern wheeled passenger vehicles.

10. **Results from Yellowstone National Park Winter Air Quality Study 2004-2005.** Ray, J.D. (2005) National Park Service, U.S. Department of Interior Air Resources Division. http://www.nps.gov/yell/parkmgmt/upload/winteraqstudy04-05.pdf

Summary of Results: Ambient monitoring during the winter activity season was conducted at Old Faithful and at the West Entrance for the air pollutants, carbon monoxide (CO) and fine particulate matter (PM2.5). Summertime measurements at the West Entrance and vehicle entrance counts were used to compare to the winter season. Results from the ambient monitoring and a closely related emissions study are presented:

- CO was lower during the winter 2004-2005 season than in previous years at both monitoring stations and well below the level of the national standard.
- PM2.5 was also lower this season than in previous years at the West Entrance. Both locations are below the level of the standard.
- The historical decreasing trend in the number of snowmobiles is mimicked by decreasing CO concentrations and is the primary reason for the lower ambient CO concentrations.
- Sources of PM2.5 other than snowmobiles are contributing to the observed PM at Old Faithful. The greatest amount of PM2.5 at Old Faithful is now from Snow Lodge and from the uncontrolled wood stoves in the warming huts.
- Summer traffic with wheeled-vehicles contributes a much smaller amount of CO and PM than winter activity with snowmobiles and snowcoaches, despite much greater numbers of vehicles in summer.

11. **Laboratory Testing of Snowmobile Emissions.** Lela, C.C. & White, J.J. (2002) Southwest Research Institute (SwRI 08.05486) for the National Park Service and Montana Department of Environmental Quality.

Executive Summary: Snowmobile engine emissions are of concern in environmentally-sensitive areas, such as Yellowstone National Park. A program was undertaken to measure emissions from commercially-available four-stroke snowmobiles, as well as student-designed snowmobiles, and to compare their emissions to two-stroke sleds. Test vehicles included a 2002 Arctic Cat 4-Stroke Touring snowmobile, a 2002 Polaris Frontier 4-stroke engine, and two 4-stroke snowmobiles that competed in the 2002 SAE Clean Snowmobile Challenge (CSC). Fuels used were a reference gasoline and E10/gasohol (10 percent ethanol). For comparison, one of the student-designed snowmobiles was also tested on E85 (85 percent ethanol) to examine potential emission benefits with this fuel.

Emission were measured using three different test protocols including the five-mode ISMA/SwRI snowmobile engine dynamometer test cycle, a four-mode chassis dynamometer cycle, and at snowmobile speeds of 15, 25, 35, and 45 mph, as well as top speed on the chassis dynamometer. Emissions measured included hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), carbon dioxide (CO_2), and particulate matter (PM). Selected Arctic Cat engine tests also determined individual hydrocarbon species (C_1-C_{12}), including ketones, aldehydes, and alcohols. The following observations were made:

- Commercially-available 4-stroke snowmobiles are significantly cleaner than 2-stroke sleds. Compared to previously tested 2-strokes, these 4-stroke sleds emit 98 – 95 percent less HC, 85 percent less CO, and 90 – 96 percent less PM. Four-stroke snowmobile NO_x, however, is considerably higher than from a 2-stroke, being increased by a factor of seven to twelve.

- The commercially-available 4-stroke snowmobiles emit roughly 90 percent less toxic hydrocarbons, such as 1,3-butadiene, benzene, formaldehyde, and acetaldehyde, than 2-strokes.
- Four-stroke snowmobiles achieve approximately 40 percent better fuel economy than 2-stroke sleds.
- Use of a catalyst can further reduce snowmobile emissions. The University of Idaho CSC 2002 sled, that incorporates a 4-stroke, closed-loop controlled engine with catalyst, generated the lowest emissions of all sleds tested. Compared to the 4-stroke Arctic Cat sled, the Idaho sled emitted 64 percent less HC, 29 percent less CO, 99 percent less NO_x, and 36 percent less PM.
- Operation on E10 generally produced lower HC and CO emissions, but higher NO_x emissions, compared to reference gasoline.

12. **Review of Research Related to the Environmental Impact Statement for the Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr. Memorial Parkway.** (2000) University of Wyoming, Institute of Environment and Natural Resources; p 19-45. http://wyotrails.state.wy.us/pdf/review.pdf

Executive Summary: Air Quality Issues Pertaining to Yellowstone National Park Studies – the studies by Carroll and White (1999), White and Carroll (1998) and Morris et al (1999) together give good information on snowmobile engine emissions. It is clear that snowmobiles that use 2-srtoke engines emit substantially higher hydrocarbon (HC) (approximately factor of 50) and particulate matter (PM) concentrations (approximately a factor of 100) than similar size 4-stroke engines. Emissions of carbon monoxide (CO) and oxides of nitrogen (NOx) are broadly similar. Off-road vehicle emissions are at present unregulated, and as such, manufacturers of snowmobiles have no incentive to attempt to reduce emissions from snowmobile engines. (*NOTE: this has since changed*) Substantial pollution emission reductions would be achieved by adopting direct injection 2-srtoke engines. Levels would be further reduced if 4-stroke engines were used. The adoption of catalytic converters would reduce pollutant emissions further still. However, at this time, emission standards are still in the development stage.

The studies by Morris et al. (1999) and Kado et al. (1999) provide some degree of assessment of the impact of snowmobile use on the air quality of YNP. While both studies suffer from methodological issues some broad conclusions can be drawn. Various measurements at the West Entrance site reveal that concentrations approaching National Ambient Air Quality Standards (NAAQS) and Occupational Health and Safety Administration Standards (OSHA) are being measured. While the studies do not directly assess these standards, other work by the Montana Department of Environmental Quality (MDEQ) that does claim to meet EPA protocols, has reported concentrations almost equal to the NAAQS. Therefore, it is clear that there is a genuine air quality problem. It is interesting to note that atmospheric deposition data by U.S. Geological Service (1999) indicates that water quality is probably not threatened at present.

The National Park Service (2000) report is an excellent summary paper of the YNP air quality issue with respect to snowmobile usage. It is evident that the problem can be seen as an ambient air quality issue with respect to NAAQS, a workplace exposure issue with respect to OSHA standards and a Clean Air Act issue with respect to the Class I status of Yellowstone National Park.

For the first two issues it is also clear that the entry point of West Entrance is the primary cause for concern. Pollution levels may be reduced by redesigning the entrance area at West Yellowstone. The kiosks could be separated in a manner to enhance dispersion.

Alternatively, pollution from snowmobiles entering the park should be reduced. This can either be achieved by reducing emissions from snowmobiles or reducing the number of snowmobiles. In the short term, the latter is the only viable solution. Emission control legislation, even if passed tomorrow, will take time to affect the overall fleet emission profile. Thus, in terms of the NAAQS and OSHA limitation of snowmobile use would be a viable solution if the relevant standards were exceeded.

The situation is less clear for meeting the requirements of the Clean Air Act. The Class I status of YNP means that the highest level of protection is required. If, for example, scenic vistas are being affected by snowmobile emissions then this would be a violation of the stated Clean Air Act goal of "the prevention of any future, and remedying of any existing, impairment in mandatory Class I Federal area which impairment results from manmade air pollution."

The National Park Service (2000) states that management Policies are clear that in cases of doubt as to the impacts of existing or potential air pollution on park resources, the Park Service will err on the side of protecting air quality and related values for future generations.

In order to meet the requirements of Class I status it would again appear that one of two options could be justified, namely emission reduction or emission elimination. The latter option would be a ban on snowmobiles. This approach would be harder to justify given that automobiles and snow coaches would presumably still be allowed within National Parks. If emission level is the issue, maybe the use of 4-stroke snowmobiles needs to be considered. If a ban is put in place based purely on air pollutant emissions, then the question remains as to whether these types of snowmobiles would be allowed entry to YNP.

It is clear from the reports evaluated that more monitoring and modeling is required. This work should focus on whether ambient or workplace air quality standards are being exceeded and whether the Clean Air Act with respect to the Class I status of YNP is being violated.

An assessment of the validity of any decision is not possible since a final decision with respect to snowmobile use has not yet been made. Furthermore, it is inappropriate for a "second guess" since we do not at present have access to all the information used to make this decision.

13. **Real-time Remote Sensing of Snowmobiles Emissions at Yellowstone National Park: An Oxygenated Fuel Study.** Morris, J.A., Bishop, G.A. and Stedman, D.H. (1999) University of Denver, Department of Chemistry and Biochemistry

Executive Summary: In the winter of 1999, the University of Denver conducted a remote sensing study at Yellowstone National Park. The objective of the study was to identify the effect of oxygenated fuels on the exhaust emissions from snowmobiles. Ratios of CO, HC and toluene to CO2 were measured and used to calculate %CO, %HC and parts per million of toluene. From the measured ratios we also calculated the grams per gallon of fuel, grams per mile and grams per kilogram of fuel for CO and HC. The ambient air temperature was collected and correlated to the remote sensing measurement to account for temperature effects.

Measurements of CO and HC were made at the West Entrance, South Entrance and west exit of Yellowstone where there were 974, 376 and 163 valid readings respectively. The mean CO exhaust emissions in percent were 6.0, 6.4 and 7.1 respectively and the medians were 6.1, 6.5 and 7.4. For CO emissions of snowmobiles the observed distribution looks normal compared to the observations from automobiles where their distribution is very skewed with most measurements low and very few high emitters. At the West Entrance where an ethanol blend was used in the snowmobiles there was a 7 ± 4% decrease, corrected for temperature, in CO emission compared to the South Entrance where nonoxygenated fuels were used. The mean HC emissions measurements in percent were 2.5 for the West Entrance, 2.2 for the South Entrance, and 2.0 at the West Exit and the medians were 2.5, 2.1 and 1.9 respectively. Since HC emissions from snowmobiles are variable with many different parameters that could not be controlled, an ethanol effect could not be c1early identified and an ethanol penalty cannot be discounted.

The first ever measurement of aromatics from mobile sources in realistic operation was made at the West Entrance of Yellowstone. There were 470 valid measurements made for toluene. The mean was 1976ppm and the median was 1734ppm. The data show, on average, a correlation between higher HC emissions and higher reported toluene measurements with $r2 = 0.93$ with an equation ppm toluene = 0.105 * ppm HC - 619.

14. **Emissions from Snowmobile Engines Using Bio-Based Fuels and Lubricants.** White, J.J. and Carroll, J.N. (1998) Southwest Research Institute for the State of Montana Department of Environmental Quality

<u>Executive Summary:</u> Snowmobile engine emissions are of concern in environmentally sensitive areas, such as Yellowstone National Park (YNP). A program was undertaken to determine potential emission benefits of use of bio-based fuels and lubricants in snowmobile engines. Candidate fuels and lubricants were evaluated using a fan-cooled 488-cc Polaris engine, and a liquid-cooled 440cc Arctic Cat engine. Fuels tested include a reference gasoline, gasohol (10% ethanol), and an aliphatic gasoline. Carburetor jets were not changed between fuels. Lubricants evaluated include a bio-based lubricant, a fully synthetic lubricant, a high polyisobutylene (PIS) lubricant, as well as a conventional, mineral-based lubricant. Emissions and fuel consumption were measured using a five-mode test cycle that was developed from analysis of snowmobile field operating data. Emissions measured include total hydrocarbons (THC), carbon monoxide (CO), nitrogen oxides (NOx)' carbon dioxide (C02), particulate matter (PM), polycyclic aromatic hydrocarbons (PAH, both particulate bound and vapor-phase), individual hydrocarbon species (C1-C12 and C13 - C22), ammonia, and sulfur dioxide.

The following observations were made:

- Gasohol produced 16 percent less HC, 9 percent less CO, and 24 percent less PM emissions compared to gasoline with the fan-cooled engine. NOx emissions were slightly increased, and engine power was about the same.
- The liquid-cooled engine was less sensitive to fuel differences than the fan-cooled engine. With gasohol, CO and PM were reduced 6 percent and 3 percent, respectively, compared to gasoline. Oxides of nitrogen emissions increased 6 percent, and HC emissions increased 5 percent. PM emissions were more than double those of the fan-cooled engine.
- Proper engine setup for temperature and elevation is important. HC, CO, and PM emissions were all significantly increased by richer operation resulting from incorrect setup.
- Lubricant formulation affects PM emission rates. The high PIB TORCO Smoke-less lubricant created significantly less PM than the three other lubricants tested.
- Particulate emission levels are influenced by lubrication rate, and may also be influenced by engine cooling system design. The fan-cooled engine had significantly higher spark plug seat temperatures (and, by inference, cylinder temperatures), and substantially lower PM emissions, than the liquid-cooled engine.
- The aliphatic fuel, while increasing total hydrocarbon emissions, yielded the lowest ozone formation potential of the three fuels tested. It also yielded the lowest benzene emissions.
- Toxic hydrocarbon species are present in snowmobile exhaust in proportions similar to those observed from other sources such as passenger cars fueled with gasoline.

Results show that moderate reductions in emissions can be achieved in the near term through the use of gasohol and low PM lubricants. Subsequent to this project, gasohol was used extensively in snowmobiles in the YNP area during the winter of 1997/8. Both National Park Service and rental sleds operated out of

West Yellowstone, Montana were fueled with gasohol. The visible haze associated with snowmobile operation in congested areas was reportedly reduced compared to the previous winter. Operators reported excellent service with gasohol noting equivalent performance, and reduced engine maintenance. No fuel freeze ups were reported. Further studies of snowmobile particulate matter emissions and infield emissions are planned for late 1998.

ECONOMICS

Snowmobilers in the United States and Canada spend over $28 billion on snowmobiling each year according to the International Snowmobile Manufacturers Association (ISMA). This includes expenditures on equipment, clothing, accessories, snowmobiling vacations, etc. Surveys show that, on average, snowmobilers taking overnight trips (24% of those surveyed) take three to five trips per year, spending two nights per trip away from home.

Snowmobiling is responsible for "spin-off" economic benefits such as:

- Jobs for tens of thousands of people; jobs which enable those people to further stimulate the economy through additional expenditures on goods and services; jobs which provide significant income tax revenues to State and Federal treasuries and dramatically reduce unemployment and welfare payments.
- Millions of dollars in tax revenues derived from snowmobile-related businesses (including, but not limited to manufacturers, suppliers, distributors, dealers, resort and hotel facilities, restaurants, service stations, insurance agencies, hardware stores, banks, credit unions, etc.).
- Millions of dollars in winter tourism.
- Spending which support local Snowbelt economies.
- Millions of dollars in local and State sales and gas tax revenues.
- Snowmobiling has rejuvenated the economies of many communities.

Because of the economic benefits of snowmobiling to local communities, State and local travel bureaus and tourism agencies are now actively promoting snowmobile tourism through such means as the production of snowmobile information guides and trail maps and the establishment of toll free numbers with information on snowmobiling opportunities and conditions.

The economic benefits of snowmobiling to local communities and States are very significant. Many States have commissioned studies to determine specific economic impacts, which can be an extremely beneficial tool when working for snowmobiling access and favorable snowmobiling legislation.

Economic benefits may vary from State-to-State or region-to-region within States based upon ratios of local/resident riders (lower total spending) versus levels of non-resident and non-area riders (higher total trip expenditures). Results may also vary based upon research study methodologies and how local spending multipliers are applied to survey results. It is also important to recognize that visitor spending typically has grown quickly (rising costs of fuel, lodging, equipment, etc.), so studies should be regularly updated every five to ten years to remain valid. A sampling of State survey results includes:

Alaska: The economic impact of snowmobiling in the Anchorage and Mat-Su Borough was found to be over $35 million annually, according to a study conducted by the Anchorage Economic Development Corp., which was released in May 2000.

Idaho: A 2017 report by Boise State University estimated that snowmobile owners spent over $197.5 million on snowmobiles, related equipment, fuel, lodging, food and other retail items between July 2015 and June 2016. This spending is estimated to support 4,062 jobs while generating $108.2 million in labor income, while increasing value added by $160.7 million and output of locally produced goods and services by $157.3 million.

Iowa: Iowa State University completed an Economic Impact report in 2005 on snowmobiling in Iowa. Their report shows snowmobiling generated $65.4 million in economic activity resulting in 899 jobs. http://www.iowasnowmobiler.com/issa/econimpstudy.PDF

Maine: The Economic Contribution of Snowmobiling in Maine report was prepared by the University of Maine in collaboration with the Maine Snowmobile Association and Maine Department of Agriculture, Conservation and Forestry. It concluded that snowmobiling generated $459 million in direct spending across many sectors during the 2018-2019 winter season. Accounting for indirect and induced economic activity, the contribution of snowmobiling to Maine's economy was over $606 million. Snowmobile related spending also directly supports 2,279 jobs in the state of Maine and indirect and induced effects of the spending support an additional 1,060 jobs.

Trip-related spending accounted for approximately $209.5 million, or about 46%, of the total direct spending for the 2018-2019 season. Trip-related expenditures include but are not limited to, gas/oil for a snowmobile, gas/oil for a tow vehicle, restaurant purchase, souvenirs, clothing purchased during the trip, and overnight accommodations. The greatest amount of direct spending in a single category was for snowmobile purchases, which generated approximately $132 million in direct spending.

Massachusetts: The University of Massachusetts found the economic impact of snowmobiling to be $54.7 million annually in a study conducted in 2003. http://www.sledmass.com/economic.php

Michigan: Michigan State University completed an assessment of snowmobiling impacts in the State of Michigan for the Michigan Department of Parks and Recreation in February 1998. The survey showed that the average snowmobiler in Michigan spends $4,218 annually on snowmobiling activity, equipment, and vacationing within the state of Michigan. Additionally, over $1 billion in economic impact is generated and over 6,455 full time jobs are created by snowmobiling in Michigan.

Minnesota: The University of Minnesota Tourism Center completed an analysis of the snowmobile industry in Minnesota in 2005 and reported the snowmobile industry generates substantial tax revenues at the state and local level. Over $51 million in taxes were paid at the local and State level directly related to snowmobiling activity.

Montana: University of Montana Bureau of Business and Economic Research study titled Montana Recreational Snowmobiles: Fuel-Use and Spending Patterns 2013 determined snowmobiling generates $110.6 million annually in Montana. Nonresident snowmobilers spend about $147 per activity day on food, lodging and snowmobile rental costs generating an aggregate of nearly $14.3 million per year. Resident snowmobilers' annual spending totals about $96.3 million with over half attributed to gasoline for snowmobiles and transportation to riding areas. Resident and nonresident snowmobilers together buy about 4.3 million gallons of gasoline per season, generating over $1.2 million for the state highway trust fund.

New Hampshire: Plymouth State University and New Hampshire Snowmobile Association conducted a study in 2004 showing the economic impact of snowmobiling in the State of New Hampshire to be $1.2 billion annually.

New York: The New York State Snowmobile Association, in cooperation with SUNY Potsdam, performed an economic impact analysis in 1998 showing that the economic impact of snowmobiling in New York State was estimated to be $476.2 million. In 2003 the State of New York surveyed snowmobilers in New York and calculated the economic impact of snowmobiling in New York had increased to $875 million annually - an increase of 84% in 5 years!
1998: http://www.nysnowmobiler.com/images/pdf/1998_snowmobile_economic_impact_study.pdf
2003: http://www.nysnowmobiler.com/images/pdf/2003_snowmobile_economic_impact_study.pdf

Another economic assessment undertaken by the SUNY Potsdam Institute for Applied Research during the winter of 2011-2012 – which was an extremely poor snow year in New York State – shows that the sport of snowmobiling continues to deliver an economic impact of more than $860 million to New York

State annually. Consequently, even when lower than average snowfalls across the state didn't allow snowmobilers to spend the usual amount of time on their sleds, snowmobiler spending remained significant. Results of this economic assessment show that on average, a New York State snowmobiler spends more than $3,000 individually every year for snowmobile related activities.

- 2011-12 Snowmobile Owners Survey
- Profile of Snowmobiling Households
- Discussion of the Snowmobile Owners Survey

North Dakota: Development of the North Dakota Snowmobile Program Strategic Plan (2008-2012) included an assessment process that identified snowmobiling trends and issues. This assessment was conducted by Agency MABU in the summer and fall of 2007 and included face-to-face or phone interviews with several key leaders affiliated with Snowmobile North Dakota and a public input survey to assess strategic issues and activities for North Dakota's snowmobile program.

- Research Study & Final Report
- Strategic Plan 2008-2012

Oregon: A 2015 survey conducted by Oregon State University found that Oregon resident snowmobilers are estimated to engage in 352,500 snowmobile use days while spending an estimated $15 million per year on their day and multi-day snowmobiling trips. When combined with trip expenditures by out-of-state snowmobilers riding in Oregon, total spending is estimated to exceed $18 million, support 155 jobs, and generate approximately $5 million in labor income and $7.7 million in value added.

Pennsylvania: The Lebanon Valley College of Pennsylvania, in cooperation with the Pennsylvania State Snowmobile Association, conducted an updated economic impact study in 2000 showing the annual economic impact of snowmobiling in Pennsylvania to be approximately $161 million.

South Dakota: A 2011 study by the University of South Dakota found that the snowmobiling industry generates approximately $131.6 million in annual economic impact to South Dakota. Snowmobile trails were found to be a valuable state resource and study findings included:

- More than $15 million in lodging, restaurants, gaming, and other trip-related spending
- Over $58 million in revenues to South Dakota snowmobile retailers and distributors
- Direct and indirect support of over 1,400 full-time jobs.

http://gfp.sd.gov/to-do/snowmobile/docs/snowmobile-economic-impact-study.pdf

Utah: A 2017 analysis of The Economic Impact of Snowmobiling in Utah conducted by the Institute of Outdoor Recreation and Tourism at Utah State University determined that 79% of resident Utah snowmobilers' activities involved 8-hour-long daytrips, while 21% were overnight trips that averaged being 2.9 days long. This snowmobiling activity generated $138.2 million in local industry sales, $88.4 million in value added to the state's economy, 1,378 Utah jobs which generate $59.9 million in labor income, and over $13 million annually in state and local tax revenues. It also found that Utah riders are highly educated, 35% having some college or technical training with an additional 53% having a Bachelor's degree or higher. The average trip covered 67 miles while the average rider was a 54-year-old white male with an average of 3.4 snowmobiles per household. Notably, two-thirds of riders reported a household income of $90,000 or more. Additionally, nearly 70% of responding households stated no one in their household had ever taken a snowmobile education course and no one in 57% of these households had ever taken an avalanche education course.

Vermont: The economic significance that the sport of snowmobiling has on the State of Vermont exceeded $600 million annually, according to a study by Johnson State College compiled in 2003.

Washington: In 2001 Washington State University and the Washington State Snowmobile Association conducted a snowmobile usage study that concluded the annual economic impact of snowmobiling in Washington was $92.7 million.

Wyoming: The 2011-2012 Wyoming Comprehensive Snowmobile Recreation Report was prepared by the University of Wyoming and analyzed monies spent on items like equipment, gasoline, service, lodging, and food. This study concluded that snowmobiling is responsible for $146.8 million in annual direct visitor spending which results in another $29.0 million in secondary activity in the Wyoming economy. The report estimates that this $175.8 million in total economic activity supports the equivalent of 1,300 annual jobs with labor income of $35.3 million. Additionally the report estimates snowmobiling generates $7.4 million in state and local government revenue in Wyoming.

A Summary of Key Findings indicates that $31.1 million in annual trip expenditures and $53.1 million in annual equipment expenditures are attributed to Wyoming residents while $30.4 million in trip expenditures and $10.9 million in annual equipment expenditures are attributed to nonresidents of Wyoming. The report also shows $21.3 million in annual trip expenditures by snowmobile outfitter clients (people on a guided trip or rental snowmobiles) while they are in Wyoming. Gasoline was cited as the largest trip cost for both resident and nonresident snowmobilers (46% and 33% respectively of average trip expenses) while lodging was the largest trip cost (31%) cited by outfitter clients.

PERSONAL EXPOSURE

The 'personal exposure' of snowmobilers and employees to 'toxic fumes' caused by snowmobile exhausts is sometimes raised by snowmobiling opponents in public lands planning processes. Like most other recent snowmobile-related issues, this topic has been fully addressed during the lengthy Yellowstone National Park Winter Use planning efforts. The most recent reports are summarized below.

1. **Comparability Assessment of Snowmobile and Snowcoach Transportation Event Impacts to Park Resources and Values and the Visitor Experience.** Yellowstone National Park Winter Use Plan – Supplemental Environmental Impact Statement, Appendix A **(**February 2013) National Park Service
   https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

See #1 (page 4) in the Air Quality section.

2. **Personal Exposure Monitoring of Entrance Station Employees at West Yellowstone Entrance – President's Weekend 2009.** Memo from Industrial Hygienist, Office of Occupational Health and Safety, Department of the Interior (2009)
   http://www.nps.gov/yell/parkmgmt/upload/draft_pemr_2009.pdf

Summary: Personal monitoring of employees was conducted at West Yellowstone entrance to evaluate exposure to components of engine exhaust using standard industrial hygiene techniques. These contaminants included carbon monoxide, aldehydes such as formaldehyde, acetaldehyde and acrolein, and common hydrocarbons. Noise monitoring was also performed. All results were below OSHA, ACGIH, and NIOSH occupational exposure limits. The new ventilation system in the entrance station booths was not operating during the survey. It is recommended that this system be utilized during the high traffic volume periods to maintain positive pressure in the booths to further limit exposures.

Results: Personal exposures to the organic solvent contaminants were well below the OSHA permissible exposure limits and the ACGIH threshold limit values. Most were below the detectable limits. The types of chemicals detected were slightly different than last year's samples which may be the result of slightly different fuel mixtures. For example ethyl and isopropyl alcohols were not detected on the 2009 samples. Petroleum distillates were detected in slightly higher concentrations than last year's results but several orders of magnitude below a level of concern.

Carbon monoxide concentrations were slightly higher this year with an average 8-hr exposure of 1.3 ppm compared to last year's average of 0.4 ppm for entrance station employees (the 8-hr TWA corrects for differences in sampling time and represents their full shift exposure). This difference may be due to the absence of ventilation in the booths. Although these concentrations are relatively low, utilizing the positive pressure ventilation system in the booths would likely lower the carbon monoxide exposures further.

The aldehyde samples were well below the OSHA, ACGIH, and NIOSH exposure limits. The detection limit for the SEP-PAK cassette sampler using the 500 cc/min flow rate was generally an order of magnitude lower than the XAD tube sampling in 2008. Acrolein was not measured above the limit of detection in any of the samples and acetaldehyde was present in just one of the samples.

The peak noise exposure was 91 A-weighted decibels (dBA) and the time weighted average exposures were 69.1 dBA and 67.3 dBA. These are well below the OSHA action level and are consistent with last years noise exposures. Inclusion in a hearing conservation program is not warranted for this level of exposure.

3. **Yellowstone Winter Use Personal Exposure Monitoring.** Spear, T.M., Hart, J., & Stephenson, D.J. (2006) Rocky Mountains Cooperative Ecosystem Studies Unit; Montana Tech of the University of Montana and Boise State University.
   http://www.nps.gov/yell/parkmgmt/upload/personal_exposure.pdf

Executive Summary: In January 2006, the National Park Service contracted with Montana Tech of The University of Montana and Boise State University to evaluate employee exposure to air contaminants and noise associated with snowmobile operations in Yellowstone National Park. The exposure evaluations were performed at the Park's West Entrance during the 2006 President's Day three-day weekend (February 18, 19, and 20). Further noise evaluations were also performed in Mammoth on February 27, 2006.

The employee exposure evaluations were performed during anticipated peak levels of snowmobile use in an attempt to obtain worst-case measurements during winter use work activities. Personal and area air sampling and noise monitoring were performed on Yellowstone National Park's West Entrance personnel and a park ranger. Personal and area air samples were collected for the following contaminants:

- Aldehyde screen
- BETX (benzene, ethyl benzene, toluene, and xylenes)
- Total hydrocarbons
- Volatile organic compounds (VOCs)
- Carbon Monoxide
- Respirable particulate matter (2.5 um, 4.0 um, and 10 um)
- Noise

With the exception of VOCs, the results of the current study were compared to established occupational exposure limits. These limits include permissible exposure limits (PELs) established by the Occupational Safety and Health Administration (OSHA), threshold limit values (TLVs) established by the American Conference of Governmental Industrial Hygienists (ACGIH), and recommended exposure limits (RELs) established by the National Institute of Occupational Health (NIOSH). VOC results were compared to Minimal Risk Levels (MRL) established by the Agency for Toxic Substance and Disease Registry (ATSDR). All employee exposures to the above air contaminants and noise were well below established occupational limits and MRLs except two short term benzene samples. The benzene samples were above the intermediate-duration inhalation exposure of 0.006 ppm, but below the acute-duration inhalation exposure of 0.009 ppm. The intermediate- duration is used for exposures from 14-364 days per year and the acute- duration is for exposure of less than 14 days per year.
The results from the current study were also compared with the 2005 study to evaluate trends in Park Service personnel exposure to winter use vehicle emissions. Comparison of the 2005 study results with previous studies showed a general decrease in exposure to aldehydes, BETX, VOCs, and respirable particulate matter.

4. **Yellowstone Winter Use Personal Exposure Monitoring.** Spear, T.M., Hart, J., & Stephenson, D.J. (2005) Rocky Mountains Cooperative Ecosystem Studies Unit; Montana Tech of the University of Montana and Boise State University.
   http://www.nps.gov/yell/parkmgmt/upload/personalexposure05.pdf

Executive Summary: In January 2005, the National Park Service contracted with Montana Tech of The University of Montana and Boise State University to evaluate employee exposure to air contaminants and noise associated with snowmobile operations in Yellowstone National Park. The exposure evaluations were performed at the Park's West Entrance and Madison Warming Hut during the 2005 Martin Luther King three-day weekend (January 15th, 16th, and 17th) and the 2005 President's Day three-day weekend

(February 19th, 20th, and 21st). Employee exposure evaluations were also performed at the Mammoth Hot Springs Maintenance shop on February 7, 2005.

The employee exposure evaluations were performed during anticipated peak levels of snowmobile use in an attempt to obtain worst-case measurements during winter use work activities. Due to the absence of inversions noted during the monitoring dates of the current study, worst-case data were not collected. Personal and area air sampling and noise monitoring were performed on Yellowstone National Park's West Entrance personnel, warming hut personnel, snowmobile mechanics, and park rangers. Personal and area air samples were collected for the following contaminants:

- Aldehyde screen
- BETX (benzene, ethyl benzene, toluene, and xylenes)
- Total hydrocarbons
- Volatile organic compounds (VOCs)
- Elemental and organic carbon
- Oxides of Nitrogen
- Carbon Monoxide
- Respirable particulate matter (2.5 μm and 4.0 μm)

The results of the current study were compared to established occupational exposure limits [Permissible Exposure Limits (PELs), Threshold Limit Values (TLVs), National Institute of Occupational Health Recommended Exposure Limits (NIOSH RELs)] for all of the contaminants listed above, with the exception of VOCs. VOC results were compared to established recommended exposure limits [(Minimal Risk Levels (MRL)]. All employee exposure to the above air contaminants and noise were well below established Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs) and other established recommended exposure limits.

The results from the current study were also compared with previous studies to evaluate trends in occupational exposure to Park Service personnel. Comparison of the current study with previous studies shows a general decrease in exposure to aldehydes, BETX, VOCs, and respirable particulate matter. The results of noise exposure received by Park Service Personnel were similar to those found in previous studies with the only area of noise concern being the riders of snowmobiles whose 8-hour TWAs exceeded the OSHA Hearing Conservation Amendment and approached the OSHA Engineering Standard.

RECREATION CONFLICTS

1. **Comparability Assessment of Snowmobile and Snowcoach Transportation Event Impacts to Park Resources and Values and the Visitor Experience.** Yellowstone National Park Winter Use Plan – Supplemental Environmental Impact Statement, Appendix A **(**February 2013) National Park Service
https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

See #1 in the Air Quality section.

2. **Recreational conflict is affective: The case of cross-country skiers and snowmobiles.** Vitterso, J., Chipeniuk, R., Skar, M. and Vistad, O. (2004) Leisure Sciences 26(3): 227-243.

Abstract: The study used a novel field experiment to test the assumption that subjective feelings are important in recreation conflict. During a weekend, cross-country skiers in a popular recreation area were assigned randomly to an experimental group who were exposed to an operating snowmobile, and a control group who were not exposed. In the experimental group, skiers were asked to fill out a self-administered survey shortly after encountering a snowmobile, while skiers in the control group filled out a self-administered survey without having been exposed to a snowmobile. Survey respondents were given no clue as to the relationship of the snowmobile and survey being conducted. Results showed that relative to the control group, skiers who encountered a snowmobile had the quality of their affective experiences - as measured by feelings of relaxation, peacefulness, joy, harmony, annoyance - significantly reduced. This result points to the subjective nature of recreation conflict. Furthermore, the encounter with the snowmobile effected the participants' beliefs about the extent to which noise from snowmobiles disturbed the quality of ski-touring in general.

3. **Forests and regional development: Economic impacts of woodland use for recreation and timber in Wisconsin.** Marcouiller, D. W. and Mace, T. (1999) Madison, WI: University of Wisconsin Extension

Abstract: This study's primary objective was to research the economic impact of multiple uses of the Wisconsin's forests. Of particular relevance to issues of recreation conflict, was this study's use of importance-performance measures to investigate the compatibility of alternative forest uses. In general, the results suggest that recreational and timber production uses of the forest were compatible land uses. This was more likely to be true for hunters and motorized recreationists than with the broad category of "quiet" forest recreationists. The authors' intent was to identify the relative compatibility of alternative forest uses and they conclude that there are more compatibilities among forest use alternatives than there are incompatibilities. This runs counter to much traditional thought, both among academics and policymakers.

4. **Analyzing public inputs to multiple objective decisions on national forests using conjoint analysis.** Dennis, D. F. (1998) Forest Science 44(3): 421-429

Abstract: This study focuses on public perspectives of approach multiple-use regimes for national forests. The emphasis is not only the compatibility or desirability between different recreational uses, but also between different recreational uses and different types of forest management. This study uses a novel approach, employing a conjoint ranking survey to solicit public preferences for various levels of timber harvesting, wildlife habitats, hiking trails, snowmobile use, and off-road vehicle access in the Green Mountain National Forest. Despite high levels of conflict and extreme positions seen during public debates on these issues, the results of this study found more tempered opinions. Respondents preferred moderate levels of timber harvesting and snowmobile access and lower levels of off-road vehicle access.

They favored a mixture of mature closed canopy and younger more open forests over either extreme and were somewhat indifferent toward extending the network of hiking trails. These study illustrates one approach for determining peoples' perceptions on the relatively compatibility between different recreation uses.

5. **Conflicts on multiple-use trails: Synthesis of the literature and state of the practice (Federal FHWA-PD-94-031).** Moore, R. L. (1994). North Carolina State University, Department of Parks, Recreation, & Tourism Management.
   http://www.americantrails.org/resources/ManageMaintain/MooreConflictMgmt.html

Abstract: The National Recreational Trails Advisory Committee identified trail-user conflicts on multiple-use trails as a major concern that needs resolution. The Committee asked the Federal Highway Administration to produce a synthesis of the existing research to foster understanding of trail conflict, identify approaches for promoting trail-sharing, and identify gaps in current knowledge.

This synthesis is intended to establish a baseline of the current state of knowledge and practice and to serve as a guide for trail managers and researchers. The goal of the report is to promote user safety, protect natural resources, and provide high-quality user experiences. It reviews management options such as trail design, information and education, user involvement, and regulations and enforcement.

Trail conflicts can occur among different user groups, among users within the same user group, and as a result of factors not related to trail user activities at all. Conflict has been found to related to activity style, focus of trip, expectations, attitudes toward and perceptions of the environment, level of tolerance for others, and different norms held by different users.

This report provides 12 principles for minimizing conflicts on multiple-use trails. Although this report is about conflicts on trails, it is intended to promote cooperation and understanding among trail users and to inspire ideas that will help reduce trail conflict. It is intended to be used by trail managers, State and local trail coordinators, researchers, and trail-user volunteer organizations.

Executive Summary
The National Recreational Trails Advisory Committee identified trail-user conflicts on multiple-use trails as a major concern that needs resolution. The Advisory Committee recognized that there is a significant amount of literature and expertise on this topic, but no one source that summarizes the available information. The Committee asked the Federal Highway Administration to produce a synthesis of the existing research to foster understanding of trail conflicts, identify promising approaches for promoting trail sharing, and identify gaps in our current knowledge. This synthesis is intended to establish a baseline of the current state of knowledge and practice and to serve as a guide for trail managers.

The challenges faced by multiple-use trail managers can be broadly summarized as maintaining user safety, protecting natural resources, and providing high quality user experiences. These challenges are interrelated and cannot be effectively addressed in isolation. To address these challenges, managers can employ a wide array of physical and management options such as trail design, information and education, user involvement, and regulations and enforcement. Past research has consistently found that most outdoor recreationists are satisfied with their recreation experiences. Likewise, most trail experiences on multiple-use trails are probably enjoyable and satisfying. Conflicts among trail users do exist, however, and these conflicts can have serious consequences.

Conflict in outdoor recreation settings (such as trails) can best be defined as "goal interference attributed to another's behavior" (Jacob and Schreyer 1980, 369). As such, trail conflicts can and do occur among different user groups, among different users within the same user group, and as a result of factors not related to users' trail activities at all. In fact, no actual contact among users need occur for conflict to be felt. Conflict has been found to be related to activity style (mode of travel, level of technology, environmental dominance, etc.), focus of trip, expectations, attitudes toward and perceptions of the environment, level of tolerance for others, and different norms held by different users. Conflict is often asymmetrical (i.e., one group resents another, but the reverse is not true).

The existing literature and practice were synthesized into the following 12 principles for minimizing conflicts on multiple-use trails. Adherence to these principles should help improve sharing and cooperation on multiple-use trails.

1) Recognize Conflict as Goal Interference -- Do not treat conflict as an inherent incompatibility among different trail activities, but goal interference attributed to another's behavior.

2) Provide Adequate Trail Opportunities -- Offer adequate trail mileage and provide opportunities for a variety of trail experiences. This will help reduce congestion and allow users to choose the conditions that are best suited to the experiences they desire.

3) Minimize Number of Contacts in Problem Areas -- Each contact among trail users (as well as contact with! evidence of others) has the potential to result in conflict. So, as a general rule, reduce the number of user contacts whenever possible. This is especially true in congested areas and at trailheads. Disperse use and provide separate trails where necessary after careful consideration of the additional environmental impact and lost opportunities for positive interactions this may cause.

4) Involve Users as Early as Possible -- Identify the present and likely future users of each trail and involve them in the process of avoiding and resolving conflicts as early as possible, preferably before conflicts occur. For proposed trails, possible conflicts and their solutions should be addressed during the planning and design stage with the involvement of prospective users. New and emerging uses should be anticipated and addressed as early as possible with the involvement of participants. Likewise, existing and developing conflicts on present trails need to be faced quickly and addressed with the participation of those affected.

5) Understand User Needs -- Determine the motivations, desired experiences, norms, setting preferences, and other needs of the present and likely future users of each trail. This "customer" information is critical for anticipating and managing conflicts.

6) Identify the Actual Sources of Conflict -- Help users to identify the specific tangible causes of any conflicts they are experiencing. In other words, get beyond emotions and stereotypes as quickly as possible, and get to the roots of any problems that exist.

7) Work with Affected Users -- Work with all parties involved to reach mutually agreeable solutions to these specific issues. Users who are not involved as part of the solution are more likely to be part of the problem now and in the future.

8) Promote Trail Etiquette -- Minimize the possibility that any particular trail contact will result in conflict by actively and aggressively promoting responsible trail behavior. Use existing educational materials or modify them to better meet local needs. Target these educational efforts, get the information into users' hands as early as possible, and present it in interesting and understandable ways (Roggenbuck and Ham 1986).

9) Encourage Positive Interaction Among Different Users -- Trail users are usually not as different from one another as they believe. Providing positive interactions both on and off the trail will help break down barriers and stereotypes, and build understanding, good will, and cooperation.

This can be accomplished through a variety of strategies such as sponsoring "user swaps," joint trail-building or maintenance projects, filming trail-sharing videos, and forming Trail Advisory Councils.

10) Favor "Light-Handed Management" -- Use the most "light-handed approaches" that will achieve area objectives. This is essential in order to provide the freedom of choice and natural environments that are so important to trail-based recreation. Intrusive design and coercive management are not compatible with high-quality trail experiences.

11) Plan and Act Locally -- Whenever possible, address issues regarding multiple-use trails at the local level. This allows greater sensitivity to local needs and provides better flexibility for addressing difficult issues on a case-by-case basis. Local action also facilitates involvement of the people who will be most affected by the decisions and most able to assist in their successful implementation.

12) Monitor Progress -- Monitor the ongoing effectiveness of the decisions made and programs implemented. Conscious, deliberate monitoring is the only way to determine if conflicts are indeed being reduced and what changes in programs might be needed. This is only possible within the context of clearly understood and agreed upon objectives for each trail area. The available research on recreational conflict is helpful for understanding and managing conflicts on trails. There is a great deal we do not know, however. This report concludes by identifying many conflict-related research topics that have not been adequately explored. Some of this suggested research is theoretical in nature, and some is suggested for applied experimentation by managers in the field. Trail managers recognize trail conflicts as a potentially serious threat. Many are optimistic, however, and feel that when trail conflict situations are tackled head on and openly they can become an opportunity to build and strengthen trail constituencies and enhance outdoor recreation opportunities for all users.

6. **Perceived conflict between urban cross-country skiers and snowmobilers in Alberta.** Jackson, E. L. and Wong, R. A. G. (1982) Journal of Leisure Research 14(1): 47-62.

Abstract: This study looks at three indicators of perceived conflict between urban cross-country skiers and snowmobilers in Alberta, Canada. The results indicate that conflict between these groups is asymmetrical with skier perceiving snowmobilers interfering negatively with their activity, while snowmobilers are indifferent to meeting skiers. While snowmobilers do not have conflict with skiers on the trail, they may have negative attitudes towards skiers because of off-site confrontations. The conflict between skiers and snowmobilers is seen as being more fundamental than simply a conflict between these two activities. Cross-country skiers have an aversion to mechanization in recreation and are motivated to recreate in order fulfill needs of solitude, tranquility, physical exercises, and to develop an awareness of the natural environment. In contrast, snowmobilers are more machine-orientated, with a leaning towards socialization, adventurousness, and escapism.

7. **Conflict in outdoor recreation: A theoretical perspective.** Jacob, G.R., & Schreyer, R. (1980). Journal of Leisure Research, (Fourth Quarter 1980), 368-381. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/M-0062-conflict%20in%20outdoor.pdf

Abstract: An attempt to build a theoretical interpretation of conflict in order to assist recreation managers identify a "conflict potential." Using existing recreational conflict literature, four causes (activity, resource, expectation, and tolerance) are established, and ten propositions link these causes to conflict. A variety of inter- and intra-group actions between many different activities, such as motor boaters vs. non motor, hiker vs. trail bike, skiers vs. snowmobilers, are examined, to derive the interpretive theory.

SNOW AND TRAIL CONDITIONS

Having adequate snow cover is essential to limiting impacts from snowmobiles to the natural environment – as well as preventing damage to snowmobiles and personal injuries to riders. Therefore the 'season of use' often enters into discussions regarding appropriate time periods and snow cover for snowmobiling access.

While snowfall can be sporadic from year to year in some areas based upon local weather patterns, one good planning indicator for snow cover is SNOTEL data compiled in western States by the National Resources Conservation Service (NRCS), a U.S. Department of Agriculture agency. This data includes historic snow depths and snow water equivalent information for their extensive snow course network and is extremely helpful to determine accurate long-term snow patterns for an area. This data is available at www.wcc.nrcs.usda.gov/snow/ . Other sources of historic snowfall planning information include the United States Snow Climatology data provided by the National Oceanic and Atmospheric Administration's (NOAA) National Climate Data Center at www.ncdc.noaa.gov/ussc/mainpage.html and the National Snow Analyses provided by the National Weather Service's National Operational Hydrologic Remote Sensing Center (also a division of NOAA) at www.nohrsc.noaa.gov/ .

While scientific studies on this topic are almost nonexistent, the study listed below was completed in 2005 for the Yellowstone National Park Winter Use Plan and is a good example as to how local areas could similarly be analyzed if there is a need for a scientific look at this issue.

1. **Minimum Snow Depth Requirements for OSVs: Status Report and Suggested Best Management Practices.** Trails Work Consulting (2020) American Council of Snowmobile Associations https://www.snowmobileinfo.org/snowmobile-access-docs/minimum-snow-depth-requirements-for-osvs.pdf

Abstract: Provides background information related to issues caused by minimum snow depth rules being applied in some jurisdictions, a summary of existing snow depth rules across the U.S., and discussion about how current OSV travel guidance found in USDA Forest Service manuals affects this topic. The report also includes a discussion about snow mechanics science related to snow roads and trails, as well as how many existing 'minimum snow depth' rules fail to recognize snow science and the importance of early season snow grooming and compaction.

The report also includes **Best Management Practice Recommendations Related to Minimum Snow Depth Requirements for OSVs:**

1. **Avoid Generalized Numerical Snow Depth Standards:** Jurisdictions should resist establishing inflexible numerical snow depth measurements in order to provide the best adaptive management protocols for OSV travel management across a landscape. The development of numerical standards for OSV use is complicated by the fact that terrain and snow-cover are often extremely variable across the landscape. And snow is a complex material that changes constantly from the time it starts to develop high in the atmosphere, through all of the time it is on the ground, until it finally melts. Since snow is ever-changing and continually transformed by metamorphosis, wind, and other uncontrollable weather conditions, it can only be expected to be uniformly measured at a specific locality – and that measurement will be valid for only that particular, tiny point in time. Consequently, any measured snow depth will rarely be consistent when applied to an entire landscape versus the locality where the measurement was performed since snow depth is always subject to being smaller or larger in a different location – which could be within sight distance of the snow measurement location – as well as be different an hour, hours, or a day later depending upon atmospheric conditions at that location.

Furthermore, once a ‘minimum depth’ threshold is compacted by either trail grooming or being driven over by an OSV, snow depth falls back below the minimum depth threshold – prohibiting use – until enough new snowfall is deposited over the groomed or tracked path – illustrating the fallacy of such arbitrary standards.

In the end, numerical snow depth standards only invite needless inappropriate challenges to OSV use by those wishing to restrict their use in properly designated motorized use zones – rather than truly providing for meaningful resource protection or appropriate best practice for winter trails management. Consequently, OSV management is best served by the straightforward guiding principle of ‘where snowfall is adequate.’

2. **Do Not Exceed Six Inches of Snow Depth If an Ill-Advised Minimum Snow Depth Restriction Is Considered:** While numerical minimum snow depths are firmly not recommended and strongly advised against as a best management practice, any ill-advised minimum snow depth restrictions which are established related to being able to start trail compaction / grooming should not exceed six (6) inches of uncompacted snow depth. The first snowfalls that are processed on a trail create the base for the remainder of the winter. An early solid, smooth base of snow will help keep the trail smoother throughout the rest of the winter. Consequently, vigorous smoothing and heavy compaction is important for early snows and should be done to the greatest extent possible, depending up equipment and budget availability. Trail compaction with a packer bar, roller or drag pan should begin early in the season, as soon as adequate snow begins to accumulate, so that snow layers no more than 6 inches in depth are consistently packed from the ground up. Newly fallen snow layers should ideally be cut to 6 inches or less before compacting to ensure full compaction throughout the layer. Early snow which is allowed to accumulate to thick deep layers, as well as thick layers of newly fallen snow during the season, typically do not compact well.

3. **Recognize the Armoring Benefits from Early Season Snowmobile Compaction:** Snow compaction from snowmobile traffic helps to armor soil and underlying vegetation. Consequently, OSV use should be allowed to begin early in the season, just as soon as adequate snow cover (generally 4 to 6 inches) begins to accumulate. A snowmobile’s track and weight tend to increase the density of the trafficked snow layer. This densification makes the snow layer considerably stronger and works to ‘armor’ the underlying terrain. This is the essence of trail grooming practices, but even the weight of snowmobiles or other tracked OSVs being operated prior to grooming can cause this effect and is a particularly important, beneficial contribution to best management practices early in the winter season related to OSV use.

4. **Twelve-Inch Minimum Rule Only Appropriate in One Limited Circumstance:** OSV operation should not be allowed in *watersheds with ‘severely burned soil and detrimentally compacted, eroded and displaced soil*’ unless there is a minimum of 12-inches of snow cover. Outside this situation, any area-wide 12-inch minimum snow cover rule is generally considered unnecessarily restrictive and detrimental to proper OSV management.

2. **Forecasts of 21st Century Snowpack and Implications for Snowmobile and Snowcoach Use in Yellowstone National Park.** Tercek, M. & Rodman, A. (2016) Yellowstone Center for Resources, National Park Service, Yellowstone National Park, WY
http://journals.plos.org/plosone/article/asset?id=10.1371/journal.pone.0159218.PDF

Abstract: Climate models project a general decline in western US snowpack throughout the 21st century, but long-term, spatially fine-grained, management-relevant projections of snowpack are not available for Yellowstone National Park. We focus on the implications that future snow declines may have for oversnow vehicle (snowmobile and snowcoach) use because oversnow tourism is critical to the local

economy and has been a contentious issue in the park for more than 30 years. Using temperature-indexed snow melt and accumulation equations with temperature and precipitation data from downscaled global climate models, we forecast the number of days that will be suitable for oversnow travel on each Yellowstone road segment during the mid- and late-21st century. The west entrance road was forecast to be the least suitable for oversnow use in the future while the south entrance road was forecast to remain at near historical levels of drivability. The greatest snow losses were forecast for the west entrance road where as little as 29% of the December–March over-snow season was forecast to be drivable by late century. The climatic conditions that allow oversnow vehicle use in Yellowstone are forecast by our methods to deteriorate significantly in the future. At some point it may be prudent to consider plowing the roads that experience the greatest snow losses.

3. **Historical Snow Water Equivalent and Temperature Data for Oversnow Vehicle Travel Areas in Grand Teton and Yellowstone National Parks.** Farnes, P.E. & Hansen, K. (2005) Montana State University – Department of Earth Sciences.

Executive Summary: The objective of this report is to quantify the historic snow water equivalent and temperatures for stations in Grand Teton and Yellowstone National Parks, compare snow water equivalent with opening and closing dates of oversnow vehicle travel, and provide estimated opening and closing dates that would have been possible over the historic period of record.

Snowpack and climate data have been collected at many locations in Grand Teton and Yellowstone National Parks. Measurements of climatic variables have been taken since the late 1800s at Mammoth. Other stations were started in the early 1900s up to the late 1970s. Snow courses have been measured since the mid-1930s and SNOTEL (SNOw survey TELemetry) stations were generally started in the early 1980s. Four telemetered weather stations were installed in the upper Snake River drainage in the early 1990s.

Daily data from these stations have been analyzed for their period of record to determine the coldest temperature for each winter, when the snowpack starts to accumulate, maximum snow water equivalent (SWE) and date of maximum SWE, date snowpack melts, and various threshold values of SWE needed to sustain oversnow vehicle travel. Monthly average maximum, minimum, and average temperature and monthly precipitation have been summarized and are available on the data CD (see page 3).

There is considerable variability in how the snowpack develops and melts over the span of many years. In order to establish realistic opening and closing dates for use of oversnow vehicles on park roads, it is important to understand this variability. Using historical snow and climate measurements at locations along these travel routes can provide an insight to this variability and to the dates that OSV travel would have been possible over this historic record.

Recently, the criteria for opening the roads to the public for over snow vehicle (OSV) travel has been to open them on the Wednesday before the weekend before Christmas, usually around December 15 (thereafter, the targeted opening date). Closure typically occurred no later than the first Monday in March for the Mammoth to Norris, Norris to Madison, and Norris to Canyon roads (hereafter, generally considered to be March 4). The National Park Service closes the remaining roads on the second Monday in March (hereafter, March 11).

By comparing historical opening dates with SWE on those dates, about 25mm or 1 inch of SWE (about 250 – 300 mm or 10-12 inches accumulated snow depth) was needed for administrative OSV travel and 1.5 inches SWE was needed to open the roads to the public. This amounts to about 380 – 460 mm or 15 to 18 inches of cumulative snowfall needed for opening to the public. The threshold levels at Mammoth are less than for other areas as the point for starting oversnow travel is at higher elevation than the Mammoth

(Yellowstone Park) weather station. Historically, administrative travel south from Mammoth to Norris has occurred when the SWE at Mammoth reached about 12 mm or one-half inch SWE and public travel was permitted when SWE reached about 25 mm or one inch SWE.

Some areas of the park road system accumulate less snow than others and are more critical to opening the park roads to OSV's. For example, snowpack at Madison Junction dictates when the road can be opened between West Yellowstone and Old Faithful and West Yellowstone, Norris Junction and Canyon. Snow accumulation at Old Faithful and Lake dictate when traffic can be permitted from the South Entrance to those areas. The freeze-up of Yellowstone Lake determines when Mary Bay becomes safe for visitor travel (although the NPS often opens it before freeze-up, in part because relatively few visitors travel this route). Mammoth must have adequate snowpack to access the interior of the park from the North Entrance via Norris Junction. Moran 5 WNW at Jackson Dam and Glade Creek are critical in determining when OSV's can use local roads in Grand Teton National Park and the road from Flagg Ranch into Idaho via Grassy Lake.

Using SWE data and estimated road openings from 1949-2005, it appears that roads would have been opened to the public about 7 days after they were opened to administrative travel for the West Yellowstone-Old Faithful-Lake-Canyon-Norris-West Yellowstone loop (hereafter the "Lower Loop and West Entrance Road"). In 8 of the 57 years, roads would not have been open to administrative travel by December 15. In 16 years out of 57, public access would have been delayed until after the current opening date of December 15.

Spring closure dates closely match the date at which snowpack becomes isothermal (same temperature throughout the snowpack), which is the beginning of spring melt. Road closures due to snowmelt in the spring would have occurred earlier than March 4 in about 7 of those 57 years. Madison Junction is again a critical point for snowmobile travel on the Lower Loop and West Entrance Road; snowmelt starts there about 18 days before it begins at West Yellowstone.

For the road between East Entrance and Lake, Yellowstone Lake needs to be frozen before snow starts to accumulate in the Mary Bay area (Pers. Comm. M. Yochim). This is typically about a month after there is adequate snow on other portions of the road based on the SWE accumulation at the Lake Yellowstone station. Based on SWE and estimated road openings from 1949-2005, administrative travel would have been possible by December 15 on 55 of the past 57 years. Public travel would have been possible by Dec. 15 on 50 of the past 57 years. For the past 57 years, snowmelt has always started after March 11.

The Mammoth to Norris section would have been open to administrative travel on 34 of the 57 years (based on 12 mm SWE at Mammoth) by December 15 while only 14 out of 57 years would have been open to public travel by December 15 (based on 25 mm SWE at Mammoth). Melt would close the roads before March 4 in 24 of the 57 years.

Access from the South Entrance (Snake River Station) to Grant Village would have been open to administrative travel by December 15 in all but 3 years over the past 57 years based on criteria shown above. Public access would have been possible in 49 of the past 57 years by December 15. Melt would have closed the roads by March 4 in only one of the past 57 years.

At Madison Junction, there is neither a weather station or snow course. However, winter maximum and minimum daily temperatures and daily snow depths and snowfall have been recorded for the majority of days between the time the snow starts to accumulate and when it melts. SWE was estimated on the first of the month using snow depths from Madison Junction and densities from West Yellowstone, Old Faithful and Norris Basin snow courses. Daily data were extrapolated using daily SWE from the West Yellowstone snow pillow (a device that measures snow water equivalent by measuring the weight of accumulated snow). Norris Basin has only a snow course. The daily SWE for the Norris Basin location was estimated using the Canyon snow pillow data to estimate the SWE distribution between the monthly measurements.

Mid-winter melt can be a problem for maintaining snow on the roadways. Days between December 15 and March 1 when daily minimum temperatures remained at or above 0 degrees C or 32 degrees F and whether or not precipitation was observed, were analyzed for all sites. Some mid-winter melt occurs almost every year. In over one-half of the cases, rain was recorded. The events were fairly well distributed across the period indicating that warm minimum temperatures with or without rain can occur at most anytime during the winter. Lower elevation sites, such as Mammoth, have more frequent occurrences of mid-winter melt and rain-on-snow events than do higher elevations sites.

4. **Snowmobile Trail Bump Formation Analysis, Prediction and Modeling.** Alger, R., Gruenberg, S. and Gwaltney, G. (2000) Michigan Technological University for Yellowstone National Park

Executive Summary: The study of the formation and geometry of snowmobile generated bumps has been of interest to snowmobile designers, groomer operators and manufacturers, and snow scientists for years. Numerous small studies have been undertaken to model this formation and to determine the mechanisms involved in mogul growth, but prior to this major study the hypotheses were mostly unproven. This report and the work that leads to it, is a start to models to predict mogul formation and geometry.

It is well known that where there are snowmobiles traveling, there will eventually be moguls. The development of these moguls is extremely important when trying to design suspensions, and also in determining the best means to groom the snow roads to minimize roughness. To complicate matters further, it appears that the suspension characteristics of snowmobiles are a major contributing factor to generation, and any alterations to the suspension, change the bumps formed. This study looks at formation in connection to weather parameters such as snow temperature, free water content, new snow, etc. It investigates present grooming practices and the differences between certain vehicles. How the snow moves and where the bumps come from is studied. How fast do the bumps form, how many snowmobiles make the snow road unbearable, along with other hypotheses made prior to the start of this test, and some that came up as it went along, are investigated.

This study is a major measurement and data analysis undertaking with the outcome being a qualitative as well as quantitative model of how bumps form. Some generalizations are as follows: 1. Bumps formed very rapidly under all weather conditions tested. 2. Bumps formed in the same locations, even over the long test period. 3. Early winter weather can have a major effect on the groomed snow roads for the entire winter. 4. Snow coaches deteriorate the snow roads differently than snowmobiles.

SOUND

Sound levels for snowmobiles have been reduced 94% since inception. Pre-1969 snowmobiles were noisy. At full throttle, these machines emitted sound levels as high as 102 dB(A) at a distance of 50 feet.

Snowmobiles produced since February 1, 1975 and certified by the Snowmobile Safety and Certification Committee's independent testing company emit no more than 78 dB(A) from a distance of 50 feet while traveling at full throttle when tested under the Society of Automotive Engineers (SAE) J192 procedures. Additionally, those produced after June 30, 1976 and certified by the Snowmobile Safety and Certification Committee's independent testing company emit no more than 73 dB(A) at 50 feet while traveling at 15 mph when tested under SAE J1161 procedures.

For comparison purposes, normal conversation at three feet produces approximately 70 dB(A).
It would take 256 78 dB(A) snowmobiles operating together at wide open throttle to equal the noise level of just one of the pre-1969 snowmobiles.

Problems with excessive noise levels do occur when irresponsible snowmobilers modify the snowmobile exhaust system or substitute the factory system with an after-market racing exhaust. In most States this practice is illegal and grossly misrepresents the sport.

The Basics of Sound and Noise: Every kind of sound is produced by vibration. The sound source may be a violin, an automobile horn, or a barking dog. Whatever it is, some part of it is vibrating while it is producing sound. The vibrations from the source disturb the air in such a way that sound waves are produced. These waves travel out in all directions, expanding in balloon like fashion from the source of the sound. If the waves happen to reach someone's ear, they set up vibrations that are perceived as sound.

Sound then depends on three things. There must be: 1) a vibrating source to set up sound waves, 2) a medium such as air to carry the waves, and 3) a receiver to detect them.

Noise is defined as unwanted sound, a definition that includes both the psychological and physical nature of the sound. The term "sound" and "noise" are often interchangeable.

How Sound is Produced and Carried: It is easy to detect the vibrations of many sources of sound. A radio loudspeaker, for example, vibrates strongly, especially when the volume is turned up. If you lightly touch the speaker cone, you can feel its vibrations as a kind of tickling sensation in your fingertips.

Sound waves are often compared with water waves but are actually a very different sort of wave. What they are can be seen by considering what happens when an object vibrated in the air. Suppose someone strikes a gong, as the gong vibrates, it bends outward and inward very rapidly. This movement pushes and pulls at the air next to the surface of the metal. Air is made up of tiny molecules, and when the metal gong bends inward and outward, it creates a wave. The wave travels outward from the gong, becoming weaker and weaker until it dies away.

The Speed of Sound: Sound waves travel at a constant speed, regardless of the loudness or softness of a sound. Temperature, however, does affect their speed. At room temperature sound travels in air at a speed of 1,130 feet per second. Sound waves travel one mile in about five seconds. At freezing (32 degrees F), sound waves travel at 1,087 feet per second or one mile in about 5 seconds.

Some sounds are high and others are low; some are loud and others barely audible; some are pleasant and others harsh. The three basic properties of any pure sound are its pitch, its intensity, and its quality.

The Pitch of Sounds: Pitch is simply the rate at which vibrations are produced. Another way to define the pitch of a tone is to find its wavelength. The wavelength of a particular tone is equal to the velocity of sound divided by the frequency of the tone.

Intensity and Tone Quality: The intensity of a sound has nothing to do with its pitch. Intensity depends upon the strength of the vibrations producing the sound. The loudness of sounds is measured in decibels (dB).

Reflecting and Forcing Sound Waves: Like light waves, sound waves can be reflected and focused. An echo is simply a reflection of sound. A flat surface, like that of a cliff or wall, reflects sound better than an irregular surface, like a tree, which tends to break up sound waves.

Specific snowmobiling related sound studies include:

1. **Comparability Assessment of Snowmobile and Snowcoach Transportation Event Impacts to Park Resources and Values and the Visitor Experience.** Yellowstone National Park Winter Use Plan – Supplemental Environmental Impact Statement, Appendix A **(**February 2013) National Park Service
   https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

See #1 in the Air Quality section.

2. **Natural Soundscape Monitoring in Yellowstone National Park December 2010 – March 2011.** Burson, S. (2011) National Park Service – Grand Teton National Park, Division of Science and Resource Management.
   http://www.nps.gov/yell/parkmgmt/upload/YNPWinter_natural_soundscape_monitoring29June11.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two shorter-term sites in Yellowstone National Park during the winter use season, 15 December 2010-15 March 2011.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 61% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over 75% for 0 (0%) of 31 days analyzed. Oversnow vehicles were audible for an average of 51% of the day near Madison Junction along the corridor between Old Faithful and the West Entrance. At Madison Junction oversnow vehicles were audible over 50% for 13 (46%) of the 28 days analyzed. The average noise-free interval between 8 am and 4 pm at Madison Junction was three minutes and 42 seconds. Oversnow vehicles were audible 24% of the day at Pumice Point Roadside along the Lake to West Thumb corridor and 44% of the day at Caldera Rim Picnic Area between Madison Junction and Norris. The average noise-free interval at Caldera Rim Picnic Area was 2 minutes and 27 seconds and four minutes and seventeen seconds at Pumice Point Roadside. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridors at the Madison Junction 2.3, pumice Point Roadside and Caldera Rim Picnic Area monitoring sites. The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible more than snowcoaches, snowcoaches often had higher sound levels, especially at higher speeds. Consistent with acoustic data collected during the previous eight winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year as trends emerge in addition to detailed information about specific winters and locations.

3. **Natural Soundscape Monitoring in Yellowstone National Park December 2009 – March 2010.** Burson, S. (2010) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2009-2010.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two winter-long sites and one shorter-term site (near a plowed road used by wheeled vehicles) in Yellowstone National Park during the winter use season, 15 December 2009-15 March 2010.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 55% of the day between 8 am and 4 pm. Oversnow vehicles were audible for an average of 54% of the day near Madison Junction along the corridor between Old Faithful and the West Entrance. At Madison Junction oversnow vehicles were audible over 50% for 18 (60%) of 30 days analyzed. The average noise-free interval between 8 am and 4 pm at Madison Junction was four minutes and 24 seconds. Wheeled vehicles were monitored in Lamar Valley at 140 feet (43m) from the plowed road between Tower and the Cooke City and were audible for 66% of the time between 8 am and 4 pm. The average noise-free interval between 8 am and 4 pm at Lamar Valley was 50 seconds. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although snowmobiles were audible more than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. Consistent with acoustic data collected during the previous seven winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year as trends emerge with the addition of detailed information about specific winters and locations.

4. **Natural Soundscape Monitoring in Yellowstone National Park December 2008 – March 2009.** Burson, S. (2009) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2008-2009.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. Acoustical data were collected at two winter-long sites and three shorter-term sites (two near a plowed road used by wheeled vehicles) in Yellowstone National Park during the winter use season, 15 December 2008- 15 March 2009.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 55% of the day between 8 am and 4 pm. Oversnow vehicles were audible for an average of 45% of the day at the two travel corridor monitoring sites; 47% of the day near Madison Junction along the busiest corridor between Old Faithful and the West Entrance, and for 26% adjacent to the road at North Twin Lake between Norris and Mammoth. At Madison Junction oversnow vehicles were audible over 50% for 8 (33%) of 24 days analyzed and 0 (0%) of 7 days analyzed at the North Twin Lake site. Wheeled vehicles were monitored and were audible at one roadside and one backcountry monitoring site; 26% at Blacktail Roadside (100 feet (30m) from the plowed road between Mammoth and Tower), and 16% at Blacktail Backcountry (one and one half mile [2.4 km] from the same section of road as the Blacktail Roadside monitor. The maximum sound levels of oversnow vehicles sometimes exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between Norris and Mammoth (North Twin Lake). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although snowmobiles were audible more than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was lower than the past five seasons, likely due to the decrease in daily average number of oversnow vehicles that entered the park; an average decrease of about 95 oversnow vehicles/day from last season. Consistent with acoustic data collected during the previous five winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can emerge in addition to detailed information about specific winters and locations.

5. **Exterior Sound Level Measurements of Over-Snow Vehicles at Yellowstone National Park** (2008) U.S. Department of Transportation – Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center – Environmental Measurement and Modeling Division, RTV-4F Cambridge, MA http://www.nps.gov/yell/parkmgmt/upload/dot_vntsc_08-03.pdf

Executive Summary: Sounds associated with Oversnow Vehicles (OSVs), such as snowmobiles and snowcoaches, are an important management concern at Yellowstone and Grand Teton National Parks. The John A. Volpe National Transportation Systems Center's Environmental Measurement and Modeling Division (Volpe Center) is supporting the National Park Service (NPS) with implementation of the Winter Use Planning program (Ref. 1, 2, 3, 4) and supporting National Environmental Policy Act (NEPA) documents, including the 2007 Winter Use Planning / Environmental Impact Statement. As part of this support, the Volpe Center, in cooperation with the NPS, performed acoustic measurements of ten snowcoaches and six snowmobiles at the southern entrance of Yellowstone National Park from the 26th through the 28th of February 2008. The measurement site location is indicated in Figure 2.

These measurements were made with three primary objectives in mind:
1) Help determine what sound testing protocols should be used to determine if *snowcoaches* meet the Best Available Technology (BAT) with respect to noise emissions.
2) Determine which *snowcoaches* meet BAT standards with respect to noise emissions.
3) Determine if there was a significant difference between *snowmobile* sound levels when tested using two different methodologies.

The measurement site was an open section of snow packed road at the south entrance of Yellowstone National Park, at the same location as was used in October 2002 for snowcoach measurements. There was a 2 to 3 foot buildup of snow in the measurement area adjacent to the road which was not ideal, however, analysis of the data indicated that this snow berm did not substantially influence the measurements.

Three microphones were setup along a line perpendicular to the road. Two were set 50 feet from the center of the over-snow vehicle travel path, one 4 feet above the snow and a second 15 feet above the snow. One microphone was set 200 feet from the center of the travel path, 4 feet above the snow. Sound levels were measured as the over-snow vehicle traveled along the roadway.

The snowcoaches tested are indicated in Table 1. Testing of the snowcoaches was guided by specifications given in SAE J1161 (Ref. 11). On the first day of testing, vehicles were measured at idle, 15 mph and 30 mph, however, due to degraded road conditions, only idle and 15 mph measurements were made on the second day. Results from these measurements are shown in Figure 1.

Snowmobiles tested are shown in Table 2. These vehicles were evaluated in order to determine if two different revisions of SAE J192 (Ref. 12) would produce different sound level results. The 1985 revision required snowmobiles to start from rest and then travel along the road at full throttle while measuring the sound level using a fast time response. The 2003 revision required snowmobiles to approach the measurement zone at 15 mph and then travel along the road at full throttle while measuring the sound level using a slow time response. On average, the 1985 revision produced results about 2 dB greater than the 2003 revision.

Based on experiences during this study, the following recommendations are suggested for future measurement of snowcoach sound levels for the purpose of testing BAT conformance. The measurements should adhere to SAE J1161 with the following modifications and considerations:

- Because of the altitude, barometric pressure specifications should be expanded to include typical pressures in the parks during the winter season. The sound level variation due to the lower barometric pressure could be corrected in a manner similar to the methods described in References 5 and 6.
- If a snow berm is present, all practical efforts to remove it should be implemented.
- If a snow berm greater than 3 feet tall cannot be removed, another site should be sought.
- Testing should be conducted for three conditions
    - Idle
    - 15 mph
    - A high speed to be determined by the park based on local speed limits, e.g., 30 mph, road speed limit, or a typical cruising speed.
- A road groomer should be kept on hand in order to ensure that the road conditions do not deteriorate over the course of the testing.
- If vehicles fail to meet BAT requirements at the high speed, consideration should be given to restrictions which would still allow the snowcoach to operate in the parks, but at a reduced speed.

6. **Natural Soundscape Monitoring in Yellowstone National Park December 2007 – March 2008.** Burson, S. (2008) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2007-2008.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the adaptive management thresholds in the 2007 Yellowstone and Grand Teton National Park Winter Use Plans Environmental Impact Statement. Acoustical data were collected at three winter-long sites and three short-term sites in Yellowstone National Park during the winter use season, 19 December 2007- 9 March 2008.

Oversnow vehicles were audible in the most heavily used developed area, Old Faithful, an average of 68% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over 75% for 2 (7%) of 27 days analyzed. Oversnow vehicles were audible for an average of 45% of the day at the two travel corridor monitoring sites. Oversnow vehicles were audible for 53% of the day near Madison Junction along the busiest corridor between Old Faithful and the West Entrance, and for 37% adjacent to the road between Grant Village and Lewis Lake along the route to the South Entrance. At Madison Junction oversnow vehicles were audible over 50% for 15 (56%) of 27 days analyzed and 3 (14%) of 22 days analyzed at Grant Village/Lewis Lake site. Oversnow vehicles were audible at one transition zone and two backcountry short-term monitoring sites; 20% at Delacy Creek Trail (one mile [1.6 km] from the groomed road), 26% at Mary Mountain 8K (one and one half mile [2.4 km] from the groomed road), and 18% at Shoshone Geyser Basin (five miles [8 km] from the groomed road). The maximum sound levels of oversnow vehicles exceeded 70 A-weighted decibels (dBA) along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and the South Entrance (Grant Village/Lewis Lake). The majority of these higher sound levels were caused by old technology snowcoaches. Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past four seasons, although there was a slight decrease in oversnow vehicle audibility at Madison Junction 2.3. The daily average number of oversnow vehicles that entered the park decreased about 2% from last season. Consistent with acoustic data collected during the previous four winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

7. **Natural Soundscape Monitoring in Yellowstone National Park December 2006 – March 2007.** Burson, S. (2007) National Park Service – Grand Teton National Park, Division of Science and Resource Management.
   http://www.nps.gov/yell/parkmgmt/upload/final_natural_soundscape_monitoring2007.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at five sites in Yellowstone National Park during the winter use season, 20 December 2006-11 March 2007.

Oversnow vehicles were audible in the Old Faithful developed area an average of 68% of the day between 8 am and 4 pm. At Old Faithful, oversnow vehicles were audible over the threshold of 75% for developed area for 9 of 35 days (26%) analyzed. Oversnow vehicles were audible 26% of the day adjacent to the road near Mud Volcano and 44% at Spring Creek 2. At Madison Junction 2.3 oversnow vehicles were

audible for 59% of the day, exceeding the travel corridor threshold average of 50%. The maximum sound levels for oversnow vehicles exceeded 70 dBA at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and Old Faithful (Spring Creek 2). Sounds from both visitor and administrative oversnow vehicles were included in this study.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past two seasons, although there was increased audibility at two locations. The daily average number of oversnow vehicles that entered the park increased about 20% from last season. Consistent with acoustic data collected during the previous three winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

8. **Natural Soundscape Monitoring in Yellowstone National Park December 2005 – March 2006.** Burson, S. (2006) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/final_soundscape.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to monitor the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at five primary sites in Yellowstone National Park during the winter use season, 21 December 2005-12 March 2006.

Oversnow vehicles were audible in the Old Faithful developed area an average of 67% of the day between 8 am and 4 pm. Oversnow vehicles were audible 35% (Old Faithful Upper Basin) and 62% (West Thumb Geyser Basin) of the day within geyser basins adjacent to developed areas. Along travel corridors the percent time audible was 34% (Spring Creek) and 55% (Madison Junction 2.3). The maximum sound levels for oversnow vehicles exceeded 70 dB(A) at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3) and between West Thumb and Old Faithful (Spring Creek). Sounds from both visitor and administrative oversnow vehicles were included in this study. Acoustic data from previous years is included for comparison.

Although on average snowmobiles were audible for more time than snowcoaches, snowcoaches in general had higher sound levels, especially at higher speeds. The overall impact on the natural soundscape from oversnow vehicles was similar to the past two seasons, although there was increased audibility at two locations. The number of oversnow vehicles that entered the park increased slightly. Consistent with acoustic data collected during the previous three winter seasons, the sound level and the percent time oversnow vehicles were audible remained substantially lower than during the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by fewer snowmobiles, the change from two to four-stroke engine technology, and the guided group requirements. The value of this monitoring study increases with each additional year because trends can begin to emerge in addition to detailed information about specific winters and locations.

9. **Modeling Sound Due to Over-Snow Vehicles in Yellowstone and Grand Teton National Parks** Hastings, A.L., Fleming, G.G., Lee, C.S.Y. (2006) Research and Innovative Technology

Administration, John A. Volpe National Transportation Systems Center – Environmental Measurement and Modeling Division, RTV-4F Acoustics Facility, Cambridge, MA http://www.nps.gov/yell/parkmgmt/upload/finalsound%20_modelingreport.pdf

Executive Summary: The National Park Service (NPS) is developing Winter Use Plans for Yellowstone and Grand Teton National Parks to help manage the use of Over-Snow Vehicles (OSV) in the parks. The use of snowmobiles in the parks is a concern because of increased use and legal actions by environmental, recreational, and commercial groups. Several modeling alternatives are being considered for the NPS Winter Use Plans. These alternatives affect the number of OSVs that are allowed to operate in the parks and where they are allowed to travel. Some modeling alternatives allow standard OSVs while others require the use of Best Available Technology (BAT) OSVs. Some modeling alternatives represent a reduction or cessation of activity while others consider increased operations. The U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center (Volpe Center) is supporting the NPS by modeling the acoustical environment in the parks associated with each modeling alternative as well as current and historical conditions.

Acoustical modeling was performed by using the Federal Aviation Administration's (FAA) Integrated Noise Model (INM) Version 6.2, adapted for use with OSVs. Model adaptation included the development of ground-to-ground sound propagation models to better account for propagation over snow-covered terrain. Ambient sound levels were provided by the NPS and a set of acoustic zones were developed in order to generate natural ambient maps for the parks. See Figure 1 and Figure 2. The Volpe Center developed Noise-Speed-Distance (NSD) relationships for OSVs based on previously published OSV acoustical studies and winter 2005-2006 measurements. Vehicle types modeled included two- and four-stroke snowmobiles, purpose built snowcoaches, and snowcoaches based on modified conversion vans with either two or four tracks.

Each modeling alternative was evaluated for an 8-hour day with temperature, relative humidity, and snow cover representative of an average day during the winter season in the parks. In order to account for increased usage during peak hours, the 8-hour day was divided into 1-hour intervals and vehicle operations were assigned based on scheduling provided by the National Park Service. Modeling alternatives are labeled 1 to 6. Each modeling alternative was designed to model a particular management alternative:

- Modeling Alternative 1 (*Continue Temporary Plan*): This alternative continues the current Temporary Plan into the future with some modifications. This alternative limits the number of snowmobiles and snowcoaches according to NPS specifications found in "Preliminary Draft Alternatives – Winter Use Plans"1, and requires that all vehicles be guided and of Best Available Technology (BAT). This alternative includes several options as follows:
    - Option A: East entrance to Yellowstone open. (Daily Entrance Limit: 720 snowmobiles / 78 snowcoaches)
    - Option B: East entrance to Yellowstone closed for avalanche control. (Daily Entrance Limit: 720 snowmobiles / 78 snowcoaches)
    - Option C: Was not modeled because the operations were adequately modeled by Option D and Ea.
    - Option D: East entrance to Yellowstone closed and reduced over-snow vehicle use. (Daily Entrance Limit: 680 snowmobiles / 78 snowcoaches)
    - Option E: East entrance to Yellowstone and Gibbon Canyon closed, reduced over-snow vehicle use. (Daily Entrance Limit: 680 snowmobiles / 78 snowcoaches)
- Modeling Alternative 2 (*Snowcoaches Only*): This alternative limits over-snow vehicles to BAT snowcoaches only and would also close the East entrance to Yellowstone. Since snowcoaches do

not operate in Grand Teton, no modeling was necessary for Grand Teton. (Daily Entrance Limit: 0 snowmobiles / 120 snowcoaches)

- Modeling Alternative 3 (*Eliminate Most Road Grooming*): This alternative eliminates grooming of most roads in Yellowstone and Grand Teton. The exceptions would be the road segment from the South Entrance to Old Faithful and the Grassy Lake Road. These two roads would continue to be groomed. (Daily Entrance Limit: 250 snowmobiles / 20 snowcoaches)
- Modeling Alternative 4 (*Expand Recreational Use*): This alternative would expand the recreational use of the parks during the winter season. For Yellowstone, BAT requirements would remain in place and about 25% of all snowmobiles would be unguided. For Grand Teton, a portion of the snowmobiles on the road segment from Moran to Flagg Ranch would be allowed to be non-BAT. (Daily Entrance Limit: 1025 snowmobiles / 115 snowcoaches)
- Modeling Alternative 5 (*Provide for Unguided Access*): For Yellowstone, BAT requirements would remain in place and about 20% of all snowmobiles would be unguided. This alternative does not increase the number of over-snow vehicles in operation, in contrast to Modeling Alternative 4. (Daily Entrance Limit: 625 snowmobiles / 100 snowcoaches)
- Modeling Alternative 6 (*Mixed Use*): This alternative allows for the use of both oversnow vehicles as well as wheeled vehicles, namely Busses and Vans. The wheeled vehicles would travel on plowed roads on the west side of Yellowstone, whereas the other road sections would be groomed for over-snow vehicle use. (Daily Entrance Limit: 350 snowmobiles / 40 snowcoaches / 100 wheeled vehicles)
- Current Condition: The Current Condition evaluates the level of *use* during the most recent winter seasons. This includes BAT requirements for snowmobiles but not for snowcoaches. The Current Condition also requires guides for all vehicles in Yellowstone, but not for Grand Teton. (Average Daily Entrance: 260 snowmobiles / 29 snowcoaches)
- Historical Condition: The Historical Condition considers a return to the 1983 Regulations guiding winter use in the parks. This would remove limits to visitor use and eliminate Best Available Technology requirements. (Average Daily Entrance: 1400 snowmobiles / 40 snowcoaches)

Percent time audible (%TAUD) contours and time above A-weighted level in seconds (TALA) were calculated for the modeling alternatives, as well as for current and historical conditions. The percent time audible contours had highest levels near the OSV travel corridors. Increases in operations increased the highest percent time audible up to a maximum of 100%. Increases in group size and the inclusion of snowcoaches that do not meet Best Available Technology (BAT) specifications increased the park area with “any audibility”. Although not intuitive, inclusion of snowmobiles that do not meet BAT specifications did not increase the park area with “any audibility”. Although these results were initially thought to be erroneous, further investigation indicated them to be correct and to be a result of the spectra associated with BAT and non-BAT snowmobiles. Specifically, the sound levels from non-BAT snowmobiles attenuated faster with increasing distance than the sound levels from BAT snowmobiles, which had greater sound energy at low frequencies. However, non-BAT snowmobile sound levels near the travel corridor were higher than BAT snowmobiles. Similar trends were found from the results of the TALA calculations.

The modeling alternatives, as well as current and historical conditions, were rank ordered based on park area associated with the Integrated Noise Model’s calculated percent time audible contours. Yellowstone rankings are shown in Figure 3 and Grand Teton rankings are shown in Figure 4 for the case of any audible events. Figure 5 shows the Yellowstone ranking for the case of audibility 50 percent of the time, i.e., these values represent the percent of park area in which OSVs are audible at least 50 percent of the 8-hour study period. The percent TAUD was generally below 20%. Because of these lower percentages, an analysis of 50% time audible was not conducted for Grand Teton.

Recommendations for further work include:

- Collect additional source data.
    - Include a greater range of vehicles and speeds to better represent the Park's OSV fleet. This should include any vehicles that make up a significant portion of the operations to be modeled, especially if no vehicles with similar acoustic characteristics have already been included.
    - Include a greater number of repetitions to provide more statistical confidence in the mean levels.
- Run controlled operations for validation, e.g. measure LAmax at several locations simultaneously for a single snowmobile.
- Run modeling alternatives for cold and warm days and humid and dry days to determine sensitivity to weather extremes.
- Run alternatives for different types of snow cover, e.g., freshly fallen snow versus ice. This will require further modeling of ground effects.
- Use park fleet distributions to weight source data for each vehicle model when estimating the mean level for each source type. For example if there are 200 Snowbuster snowcoaches and 100 Bombardier snowcoaches in the park fleet, then the Snowbusters could be counted twice and the Bombardiers could be counted once when averaging source levels.
- Conduct surveys to determine visitor responses to alternatives that can be modeled. Averaged response ratings could be correlated to acoustic metrics such as percent time audible. This would provide an understanding of what metric levels are acceptable to park visitors.

It is understood that these tasks represent a large investment of several groups' time and resources. Further discussion needs to be conducted in order to prioritize these and to determine which items are actionable for an updated version of this study.

10. **Natural Soundscape Monitoring in Yellowstone National Park December 2004 – March 2005.** Burson, S. (2005) National Park Service – Grand Teton National Park, Division of Science and Resource Management. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring_2005_final.pdf

Abstract: Sounds associated with oversnow vehicles (snowmobiles and snowcoaches) are an important management concern at Yellowstone National Park. Acoustical standards and thresholds have been defined in park planning documents for the winter use season. The primary purpose of this study was to determine the impact of oversnow vehicles on the natural soundscape. These data were then compared to the impact definition thresholds in the 2004 Yellowstone and Grand Teton National Park Temporary Winter Use Plans Environmental Assessment. Acoustical data were collected at seven sites in Yellowstone National Park during the winter use season 15 December 2004 – 13 March 2005.

Oversnow vehicles were audible in the Old Faithful developed area an average of 69% of the day between 8 am and 4 pm. Oversnow vehicles were audible 29% (Old Faithful Upper Basin) and 47% (West Thumb Geyser Basin) of the day within geyser basins adjacent to developed areas. Along travel corridors the percent time audible ranged from 55% (West Yellowstone 3.1) to 61% during Presidents Day weekend (Madison Junction 2.3). The percent time audible in backcountry areas ranged from 4% (Lone Star Geyser) to 26% (Mary Mountain 8K). Sounds from oversnow vehicles were audible at least one mile adjacent to the main motorized routes at Mary Mountain 8K and Lone Star Geyser. Oversnow vehicles operating in the Gallatin National Forest on the west boundary of Yellowstone National Park were often audible at the West Yellowstone 3.1 monitoring site, three miles away. The maximum sound levels for oversnow vehicles exceeded 70 dB(A) at Old Faithful, along the groomed travel corridor between Madison Junction and the West Yellowstone entrance (Madison Junction 2.3 and West Yellowstone 3.1).

Oversnow vehicle use was restricted on some road segments due to inadequate snow cover early and late in the winter use season. Consistent with acoustic data collected the previous winter season, the sound level and percent time oversnow vehicles were audible remained substantially lower than oversnow vehicle sounds from the 2002-2003 winter use season. The reduced sound and audibility levels were largely explained by the fewer numbers of snowmobiles used, the change from two to four-stroke engine technology, and the guided group requirement.

11. **Comparing Sound Emissions of Snowmobiles to those of Road Vehicles.** Davis, G. & Marietta, N. (2005) Michigan Technological University.

Abstract, Conclusion and Table: The focus of this paper was to examine and compare sound emissions of production trail-ridden snowmobiles to that of other everyday vehicles that travel by road such as passenger cars, motorcycles, and semi-tractor/trailers. The paper outlines the standard test used by the Society of Automotive Engineers (SAE) that all production snowmobiles must pass before they can be sold to the public, and compares these numbers to actual test data of noise emissions produced by standard road vehicles.

Conclusion: It is clearly seen that snowmobiles in fact do not make a great deal more noise than standard road vehicles. In many cases, snowmobiles are noticeably quieter. A snowmobile under full throttle emits the same sound level as a truck pulling a camper or an off-road Jeep traveling at constant highway speeds applying very little throttle. So if you refer to a worst-case scenario, a snowmobile leaving a stop sign and applying full throttle, the noise produced is still about the same as a very common vehicle simply cruising down the road.

Now if we look at the worst-case scenario in the opposite sense, a Harley Davidson motorcycle accelerating and applying nearly full throttle produces nearly six times the noise to your ear that a snowmobile driving the same way produces. In a more common example, a logging truck pulling a loaded trailer down the highway traveling at 45 mph will produce twice the noise of a snowmobile applying full throttle.

It has been demonstrated here that the common snowmobile is simply not allowed under law to produce the sound levels, under any type of driving conditions, that common road vehicles produce every day. It is illegal for a snowmobile being driven under full throttle to be as loud as a semi tractor/trailer cruising down the highway each and every day.

Table 1: Examples of Every Day Sound Levels

Sound Source	**Sound Level dB(A)**
75-piece orchestra	130
Car horn, snow blower	110
Blow dryer, diesel truck	100
Electric shaver, lawn mower	85
Garbage disposal, vacuum cleaner	80
Snowmobile (full throttle at 50 feet; maximum allowed by law)	78
Alarm clock, city traffic	70
Dishwasher	60
Leaves rustling, refrigerator	40

12. **Supplemental Over-Snow Vehicle Sound Level Measurements.** Daily, J.G. and Raap, K. (February 2002) Jackson Hole Scientific Investigations and Wyoming Department of State Parks and Cultural Resources. SAE Technical Paper Number 2002-01-2766. http://wyotrails.state.wy.us/Research/SoundLevel.aspx

Abstract: This study of over-snow vehicle sound levels was conducted to provide supplemental and additional information for preparation of the Winter Use Plan Supplemental Environmental Impact Statement (SEIS) for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway. The tests conducted in this study resulted from the analysis of previous tests conducted in September 2001. The September tests were done on a grass surface, which is permissible under SAE standards. In order to get the best data possible, these February tests were done on snow under typical winter trail conditions.

The pass-by sound level of a variety of over-snow vehicles was measured at operational speeds that would be experienced under normal use of the vehicles while in the national park units. The pass-by testing included three different types of snow coaches, two commercially available four-stroke snowmobile models, a groomer, and various two-stroke snowmobiles. All testing was conducted on the same day in the same location with the same terrain and background conditions.

Conclusion: The loudest stock over-snow vehicle at a steady state speed was a Bombardier snow coach with high exhaust, which generated 78.4 dB(A) at 30 mph. The loudest stock snowmobile was a Polaris two-stroke 500cc Wide Track, which had a peak reading of 76.8 dB(A) at 45 mph. A modified Polaris RMK 800 was the loudest vehicle tested overall, with a peak average reading of 79.7 dB(A) at 45 mph. It recorded 84.9 dB(A) under full throttle acceleration.

The quietest over-snow vehicle tested was the Polaris Frontier touring snowmobile at 20 mph. Its lowest average reading at this speed was 65.0 dB(A). Four-stroke snowmobiles averaged 65.8 dB(A) at 20 mph, while the two-stroke snowmobiles averaged 70.7 dB(A) at 20 mph. The snow coaches averaged 69.6 dB(A) at 20 mph. The Ford two-track conversion van snow coach had a low average reading at 20 mph of 65.4 dB(A), making it the quietest of the snow coaches at this speed.

These data show the sound levels of many late model snowmobiles overlap or are quieter than snow coaches under the same or similar testing conditions. The quietest snowmobile at 20 mph produced less sound than any of the snow coaches at the same speed.

The lowest average reading for a snowmobile at 35 mph was the Polaris Frontier four-stroke, with a sound level of 70.3 dB(A). The lowest average reading for a snowmobile at 45 mph was 71.6 dB(A) by both the Polaris Frontier and the Arctic Cat Four-Stroke.

The lowest average reading for a snow coach at a nominal 30 mph was 69.5 dB(A) by the Ford two-track conversion van.

For comparison, the Kettering University entry in the Clean Snowmobile Challenge (CSC) 2001 competition recorded a sound level of 72 dB(A) during the maximum acceleration event. This is on par with the levels generated by the production four-stroke snowmobiles in this testing.

Quiet snowmobiles already exist, as shown by these data. The technology is improving to make these machines even quieter than they are now. Work will need to be done not only with engine sound levels, but also with the mechanical sound generated by the track and skis, regardless of whether the over-snow vehicle is a snowmobile or a snow coach. This work is going forward with the CSC as well as by the various snowmobile manufacturers. The production sleds tested in this evaluation are showing major improvements in the control of sound emissions compared to snowmobiles of just a few years ago.

The technology appears to exist to require that over-snow vehicles meet reasonable sound regulations. However, any regulations written should reasonably consider that over-snow vehicle sound levels are not attributable to just engine sounds must also must factor in the other mechanical sounds associated with tracked vehicles. These data show clearly the best available technology for reducing sound emissions from over-snow vehicles lie with the new technology four-stroke snowmobiles. The average sound emission from the production four-stroke snowmobiles at 45 mph is 72.5 dB(A), while the average sound emission at 30 mph of the snow coaches is 74 dB(A).

13. **Over-Snow Vehicle Sound Level Measurements.** Daily, J.G. and Raap, K. (September 2001) Jackson Hole Scientific Investigations and Wyoming Department of State Parks and Cultural Resources. SAE Technical Paper Number 2002-01-1656.

Abstract: This study of over-snow vehicle sound levels was conducted to provide new and additional information for preparation of the Winter Use Plan Supplemental Environmental Impact Statement (SEIS) for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway. The pass-by sound level of a variety of over-snow vehicles was measured at operational speeds that would be experienced under normal use of the vehicles while in the national park units. The pass-by testing included four different types of snow coaches and various models of snowmobiles. All testing was conducted on the same day (in September on grass due to time constraints) in the same location with the same terrain and background conditions. Two additional 4-stroke snowmobiles were tested in January 2002 in Yellowstone National Park under typical winter conditions.

Conclusion: The loudest stock over-snow vehicle was a Ford two-track conversion van, which registered an average peak of 81.3 dB(A). The loudest stock snowmobile was a Ski Doo Summit 700, which had a peak reading of 79.8 dB(A) at 45 mph. A modified Polaris RMK 800 was the loudest vehicle overall, with a peak average reading of 81.9 dB(A).

The quietest over-snow vehicle tested during September was the Arctic Cat Four-Stroke Touring snowmobile at 20 mph. Its lowest average reading at this speed was 67.3 dB(A). Several other snowmobiles were in this range of the high 60's to low 70's at the 20 mph speed. The Bombardier snow coach had a low average reading at 20 mph of 69.9 dB(A), making it the quietest of the snow coaches at this speed.

The Polaris Frontier tested during January had an average pass-by sound level at 20 mph of 66.7 dB(A), which makes it the quietest over-snow vehicle run during this series of tests.

These data show the sound levels of many late model snowmobiles overlap or are quieter than snowcoaches under the same or similar testing conditions. The quietest snowmobile at 20 mph produced less sound than any of the snow coaches at the same speed. None of the over-snow vehicles were as quiet as the wheeled road vehicles tested, although the Dodge diesel pickup was near the lower level of the snowmobile sound envelope.

The Arctic Cat Four-Stroke tested in September was subjectively considerably quieter at 20 mph than any other over-snow vehicle tested at that time. This may be due to the fewer exhaust pulses at a given RPM as well as the clutching engagement tailored to the four-cycle engine. As the testing speed increased for this snowmobile, the mechanical sound of the track and under-dampened skis overcame the engine sound level. One observation is that this higher level of track and ski noise may be generated because of: 1) the blow-molded plastic skis on this particular snowmobile model versus a thinner profile plastic ski which appeared to generate less sound on other models, and 2) more noise and vibration emanating from the track, perhaps due to track tension, lug height, or other factors associated with track noise. Because of this, the Arctic Cat Four-Stroke was not the quietest snowmobile at speeds of 35 and 45 mph.

The lowest average reading for a snowmobile at 35 mph and 45 mph was the Polaris Frontier, with average sound levels of 70.7 dB(A) and 72.1 dB(A) respectively. As an aside, the sound level recorded during normal conversation after the September testing was 78 dB(A).

For comparison, the Kettering University entry in the Clean Snowmobile Challenge (CSC) 2001 competition recorded a sound level of 72 dB(A) during the maximum acceleration event. We would expect its sound level during steady state operation to be considerably lower than this.

Quiet snowmobiles already exist, as shown by these data. However, work to reduce overall sound levels even further needs to be done. Sound comes from the engine as well as mechanical components such as the clutch, track and skis, regardless whether the over-snow vehicle is a snowmobile or a snow coach.

The technology appears to exist to require that over-snow vehicles meet reasonable sound regulations. With the advent of four-stroke technologies for snowmobiles, sound level restrictions can be more stringent, especially in environmentally sensitive areas such as Yellowstone National Park. However, any regulations written should reasonably consider that over-snow vehicle sound levels are not attributable just to engine sounds but also must factor in other mechanical sounds associated with tracked vehicles.

14. **Factors affecting response to noise in outdoor recreational environments**. Kariel, H. G. (1990). The Canadian Geographer, 34(2), 142-149.

Abstract: Analyzes the relation between various sound sources in the outdoor environment and people's evaluations of them. Concludes that sound level alone is not a good predictor of annoyance; randomness, listener's subjective associations, and inconsistencies with expected environment were far greater factors in whether noise was considered a nuisance. Paper includes an itemized list of the decibel level of approximately 60 normally encountered activities when camping or picnicking.

15. **Portraits in sound: A study comparing ambient sounds with those generated by snowmobiles.** Wurzbach, W. F., & Freund, M. (1975). http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/SO-0007.pdf

Abstract: This study is a very technical approach to increasing the awareness of the noise environment in which we find ourselves and its impact upon our daily lives, both physically and subjectively. This study concluded that snowmobile noise is a noise source contributor but not a major contributor. Presents a method for predicting the impact of noise on outdoor recreation called the System for the Prediction of Acoustic Detectability (SPREAD). SPREAD attempts to address the phenomenon of detectable noise vs. measured ambient noise levels with a formula (and worksheets) for predicting sound levels for the purpose of deciding what is appropriate/inappropriate acoustic impact in recreation sites.

VEGETATION AND SOIL/SNOW COMPACTION

Everything we do has some effect on the environment. When a hiker steps on a flower, he or she affects the environment. When land is paved over for a bicycle path, it affects the environment. Many of the foot paths man has used for centuries still exist and are clearly visible throughout the world.

It's a fact however that a snowmobile and rider exert dramatically less pressure on the earth's surface than other recreational activities (i.e., just one-tenth the pressure of a hiker and one-sixteenth the pressure of a horseback rider). Table A2 below shows the average pounds of pressure per square inch exerted on earth's surface by various recreation travel modes (All vehicle weights include an estimated weight of 210 pounds for one person and his/her gear.).

Table 2: Pressure Exerted by Various Recreation Travel Modes

Object	Pounds of Pressure exerted per square inch
Four-Wheel Drive Vehicle	30
Horse	8
Man (hiking)	5
All-Terrain Vehicle	1.5
Snowmobile	0.5

Moreover, the snowmobile's one-half pound of pressure is further reduced by an intervening blanket of snow.

In many States snowmobiles are not classified as off-road vehicles. By both definition and management policies, these States have completely separated snowmobiles from off-road vehicles. Given adequate snowfall and responsible operation, all evidence of snowmobile operation disappears when the season changes and the snow melts.

A U.S. Department of the Interior environmental impact statement concluded: "A major distinction is warranted between snowmobiles and other types of off-road vehicles. Snowmobiles operated on an adequate snow cover have little effect on soils – and hence cause less severe indirect impacts on air and water quality, and on soil-dependent biotic communities, than other ORVs do." It further stated that, "Where snowmobiles are used exclusively over snow on roads and trails, the impact on vegetation is indeed virtually nil."

A University of Wisconsin study found that snowmobile traffic had no effect on grain yield of winter wheat, alfalfa, red clover plots, or grass legume. Species of turf grass showed slightly reduced yields at first harvest, but were not negatively affected in subsequent harvests.

Research undertaken by the University of Maine concluded that "compaction by snowmobiling does not alter the grain weight yields of alfalfa in Maine."

A Utah Water Resource Laboratory study found that snow compaction, caused by snowmobile tracks, does not damage wheat crops. Instead, the compaction increases the yield and eliminates snow mold. Erosion is also reduced.

There is no evidence that snow compaction caused by snowmobiling, ski-touring, or snowshoeing has a significant impact on the population of small burrowing animals. Since these recreations take place over a minuscule portion of the total land area, the ecosystems of burrowing animals tend to be overwhelmingly affected by natural forces such as wind-induced compaction, early and late snowfalls, temperature fluctuations resulting in thaws and freezes, etc.

Specific studies related to vegetation, soil, and snow compaction include:

General

1. **Effects of Winter Recreation on Vegetation.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 119-121. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: There is little information available describing the ecological effects of snowmobiling and other winter recreational activities on vegetation. Research cited was completed in the 1970s and focused on assessing the impacts of snowmobile use on vegetation and snow characteristics in Minnesota and Canada. Effects could potentially include impacts on snow compaction, soil temperature, vegetation, and erosion.

Management Guidelines: Adverse effects to vegetation are the result of cumulative factors. The impact of snowmobile activities on the physical environment varies with winter severity, the depth of snow accumulation, the intensity of snowmobile traffic, and the susceptibility of the organism to injury (Wanek 1973). Activities occurring on roadbeds and (most likely) trails are probably having little affect on vegetation as the areas are already compacted or disturbed. Effects of snowmobile activities on off-trail vegetation should be assessed at a landscape level.

Management or restriction of snowmobile activities should be considered in areas where forest regeneration is being encouraged as deformation patterns was observed in conifers where leaders had been removed by snowmobile activities (Neumann and Merriman 1972). Management or restrictions should also be considered in fragile or unique communities, such as riparian and wetland habitats, thermal areas, sensitive plant species habitat, and areas of important wildlife habitat, in order to preserve these habitats.

2. **Snowmobile Impact on Old Field and Marsh Vegetation in Nova Scotia, Canada: An Experimental Study**. Keddy, P.A., Spavold, A.J., & Keddy, C.J. Department of Biology – Dalhousie University, Halifax, Nova Scotia. (1979) Environmental Management, Vol. 3, No. 5, 409-415.

Abstract: A study was carried out in Nova Scotia, Canada, to experimentally assess the effect of snowmobiles on old field and marsh vegetation. Snowmobile treatments ranging from a single pass to 25 passes (five passes on five separate days) were administered. The first pass by a snowmobile caused the greatest increase in snow compaction – roughly 75% of that observed after five sequential passes. Snowmobile treatment resulted in highly significant increases in snow retention in spring. Frequency was more important than intensity in this regard.

Standing crop and species composition were measured the following summer. Standing crop in the field showed a significant reduction with increasing snowmobile use; frequency of treatment ($p< 0.01$) was more important than intensity ($p = 0.125$). *Stellaria graminea, Aster corifolius, Ranunculus repens,* and *Equisetum arvense* all showed significant ($p < 0.05$) differences in percent cover resulting from the treatment. Marginally significant changes were observed in *Agrostis tenius* and *Phleum pretense*. Marsh vegetation showed no significant effects of snowmobile treatment. This may have been because of solid ice cover during the winter.

Grasses

1. **Effects of snowmobile traffic on bluegrass.** Foresman, C.L., Ryerson, D.K., Walejko, R.N., Pendleton, J.W., & Paulson,W.H. (1976). Journal of Environmental Quality 5(2): 129-130. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0002-effect%20of%20snowmobile%20bluegrass.pdf

Abstract: Result of staged snowmobile passes, compared with undisturbed plots. Early growth was slower but late summer yields were the same. No soil compaction was detected in the treated plots. The researchers concluded that snowmobiling would adversely affect only the plots intended for early harvest. Report includes a brief bibliography.

2. **Effects of Snowmobile Traffic on Non-Forest Vegetation and Grasses.** (1974) Proceedings of the 1973 snowmobile and Off the Road Vehicle Research Symposium., Michigan State University. East Lansing, MI

Abstract: The main objective of this study was to determine the effect of varying degrees of snowmobile traffic on non-forest vegetation and grasses found in open field areas and farms throughout the Snow Belt states. The results revealed that: where snow cover exceeded 3 inches in depth there were no detrimental effects on grass or vegetation stands, their vigor, or yield; high-grade grasses recover naturally from heavy snowmobile traffic; and snowmobile traffic caused no stand reductions, but did cause a slower recovery in early spring.

3. **Snowmobile Impact on Three Alpine Tundra Plant Communities.** Greller, A.M., Goldstein, M., & Marcus, L. (1974) Environmental Conservation, Volume 1, No. 2, 101-110.

Summary: The study observed snowmobile travel on a route located on Niwot Ridge in the Front Range of the Colorado Rocky Mountains, between two weather stations operated by the Institute of Arctic and Alpine Research – University of Colorado, from November 1968 to May 1969 and from November 1969 to May 1970. General conclusions included: 1) In communities that are snow-free in winter, damage by snowmobiles was severe to lichens, *Selaginella*, and to relatively prominent, rigid cushion-plants. Part of the damage to these communities in the present study may have been due to the manual removal of rocks, necessary for the operation of snowmobiles in snow-free areas. 2) *Kobresia*, present in isolated tussocks in a cushion-plant community, absorbed the major portion of snowmobile impact. As *Kobresia* is thought to form the climatic climax community in this ecosystem, differential damage to it should seriously retard succession. 3) Snowmobile travel in uniform, closed *Kobresia* meadows inflicted much less damage to most plants, including *Kobresia* itself, than did similar travel on a sparsely vegetated community. 4) Plants best able to survive the heaviest snowmobile impact were those with small stature and little woodiness, or with buds well-protected at or below the soil surface. 5) Snowmobile traffic should be carefully restricted to snow-covered areas. Whenever this is not feasible, the least destructive and easiest alternative is travel on mature, well-vegetated *Kobresia* meadows or similar well-drained plant communities.

It should be noted that the snowmobile damage to vegetation on Niwot Ridge was probably of greater severity than would be expected from undirected recreational travel. Recreational drivers would be expected to avoid snow-free areas whenever possible, thus reducing, considerably, the impact on vegetation. Also, it is unlikely that large numbers of stones would be removed by random travel on those snow-free areas.

Soil and Snow

1. **Effect of snow compaction on frost penetration and soil temperature under natural conditions in central Maine.** Wentworth, D. S. (1972).

Abstract: The effect of snow compaction in relation to frost penetration and soil temperatures was studied on eight sample plots. Multiple linear regression analysis was used to develop regressions of three environmental variables, as well as time, upon soil temperature. Compaction of the snow cover had little effect on average soil temperature under the different treatment areas.

Winter Wheat

2. **Effects of snowmobile traffic on several forage species and winter wheat**. Ryerson, D. K., Schlough, D. A., Foresman, C. L., Tenpas, G. H., & Pendelton, J. W. (1977). Agronomy, 69 (Sept.-Oct.), 769-772. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0031.pdf

Abstract: Attempted to identify conditions under which OSV use would cause plant damage; this was not accomplished because each winter had unique and unpredictable characteristics. Six common species were studied for 3 years. 4 species showed no detrimental effects; winter wheat yields were not reduced below the check (control) areas; 1 species was significantly reduced during one year but unaffected during the next year Concluded that trail use (rather than open uncontrolled use) would be most appropriate in crop vegetation environs. Paper includes a bibliography.

Woody Plants

3. **A continuing study of the ecological impact of snowmobiling in Northern Minnesota.** Wanek, W., & Schumacher, L. H. (1975) The Center for Environmental Studies, Bemidji State University, Bemidji, MN.

Abstract: Five years of research have shown conclusively that snowmobiles have an impact on the physical environment and plant communities of northern Minnesota. The impact may vary from year to year due to differing temperature extremes and snowfall. The extent of plant injury often depends on the intensity of snowmobile traffic and the susceptibility of each species to physical or cold temperature damage. The environment beneath the snow compacted by snowmobiles is substantially colder than that under natural snow cover. This can cause damage to herbs and perennials. Many woody plants are particularly vulnerable to physical damage by snowmobiles.

The damage to plant communities reported during this study should not be considered maximal. In all cases snowmobile traffic began after six inches of snow had accumulated – a condition which is usually not met during normal snowmobiling activity.

4. **The ecological impact of snowmobiling in Northern Minnesota.** Wanek, W. (1973) The Center for environmental studies-Bemidji State College Bemidji, Minnesota.

Abstract: Snowmobiles have an impact on the physical environment and biota of northern Minnesota. The impact varies with the severity of the winter, the depth of snow accumulation, the intensity of snowmobile traffic, and the susceptibility of the organism to injury, caused by cold temperatures or physical contact. Temperatures beneath the snow compacted by snowmobiles are considerably colder than those under undisturbed snow cover. The growth of early spring flowers is retarded, and reproductive success is reduced where snowmobiles travel. Many herbs with massive underground storage organs (alfalfa included) are winterkilled in the modified environment under snowmobile tracks. Woody plants are particularly vulnerable to physical damage by snowmobiles. Snowmobile traffic can be beneficial by reducing the stature of woody vegetation in area where it needs to be controlled. However, traffic is unwise in places where forest regeneration is being encouraged, or where the esthetic or economic value of fragile communities necessitates their preservation.

WATER QUALITY (Including Snowpack and Snowmelt)

Winter recreation could affect aquatic organisms mainly by indirect impacts due to water pollution. Some believe two-stroke snowmobile engines can deposit contaminants on snow, leading to ground and surface water quality degradation, which subsequently may impact aquatic life. The following information rebuffs those claims:

1. **Snowmobile Trail Chemistry Study** Perry, M.J., (2010) VHB Pioneer, North Ferrisburgh, VT and Vermont Association of Snow Travelers, Inc. http://www.vtvast.org/VAST/Forms/Other-Resources.html

Conclusions: At the request of the Vermont Association of Snowmobile Travelers, VHB Pioneer has completed a snowpack chemistry study that has evaluated the potential environmental impacts associated with the use of snowmobiles on public lands in Vermont. This study was completed with the purpose of evaluating the presence or absence of impact from snowmobile traffic on the chemical composition of snowpack, soil, and runoff in the proximity of heavily traveled snowmobile trails in Vermont, and has provided scientifically valid conclusions about the impact that snowmobile usage has on snowpack, soil, and runoff chemistry at the sites evaluated.

Snowmobile trail usage monitoring has indicated that all sampling stations, except for the Lye Brook Wilderness reference station, were located along heavily used snowmobile trails; therefore, are appropriate for evaluation in this study. Snow samples were collected during the busy snowmobiling season to provide worst-case scenario data. Runoff and soil samples were collected after the end of the snowmobiling season, to capture the maximum amount of contaminants that would potentially have accumulated during the season.

Snowmelt and runoff chemistry monitoring indicated no detectable levels of volatile organic compounds or total petroleum hydrocarbons in surface waters that are located immediately downgradient of the snowmobile trails that were evaluated. Snowmelt samples that were taken immediately following the end of the snowmobile season did not differ in comparison with runoff samples that were taken at the beginning of the snowmobile season, which are considered representative of background water quality conditions. These data indicate that the snowmobile usage during the 2009/2010 season did not have any impact on the surface water quality in the vicinity of heavily used snowmobile trails.

Snowpack chemistry monitoring indicated that there were no detectable levels of volatile organic compounds or total petroleum hydrocarbons in background or on-trail snow sampling stations, with the exception of one chemical compound detected in an on-trail sample taken at Station B2, which is the most heavily used station in the study. 1,2,4-Trimethylbenzene was detected at a concentration of 1.3 ug/L; no regulatory standards apply to snow, but for comparison this concentration is below the drinking water standard of 5.0 ug/L. These data indicate that snowmobile usage during the 2009/2010 snowmobile season did not significantly impact snowpack chemistry in the vicinity of the heavily used snowmobile trails. Therefore, it appears that snowmobile usage has no significant impact on the chemistry of snowpack located on snowmobile trails, but may cause trace levels of volatile organic compounds within the snow, and these levels are likely to be low concentrations that meet regulatory water quality standards.

Soil chemistry monitoring indicated that there were no detectable levels of volatile organic compounds or total petroleum hydrocarbons in background or on-trail soil sampling stations, with the exception of one chemical compound detected in an on-trail sample taken at Station C1. Toluene was detected at a concentration of 24.4 ug/Kg, which is far below the EPA Soil Screening Guidance Level of 12,000 ug/Kg. At six on-trail soil sampling stations, soil chemistry monitoring also indicated detectable levels of polycyclic aromatic hydrocarbons, which most likely were present due to historic railroad use along the

Lamoille Valley Rail Trail, other historic activities, and possible natural sources such as forest fires, and tree leaves and needles. All PAH levels in tested soil were below the EPA Soil Screening Guidance Levels with the exception of one exceedence at station A4 on the LVRT, which is most likely the result of the historic railroad use and the highway adjacent to this location. These data indicate that snowmobile usage does not have any significant impact on volatile organic compounds within soil in the vicinity of the heavily used snowmobile trails that were evaluated. Trail usage by snowmobiles and other motorized vehicles may result in low levels of VOCs and PAHs in soil, that are far below applicable regulatory levels and environmental screening levels.

2. **Effects of Snowmobile Emissions on the Chemistry of Snowmelt Runoff in Yellowstone National Park.** Arnold, J.L., & Koel, T.M. (2006) Yellowstone National Park, Center for Resources – Fisheries and Aquatic Sciences Section. http://www.nps.gov/yell/parkmgmt/upload/snwmbil_snwmlt_rpt.pdf

Executive Summary: Created in 1872, Yellowstone National Park forms the core of the Greater Yellowstone Ecosystem, and is arguably the largest intact naturally functioning ecosystem remaining in the lower 48 United States. The park was created to protect the unique geothermal features and headwaters of the Madison, Snake, and Yellowstone rivers, while providing for the enjoyment of this unique environment by visitors. Approximately 44,000 hectares of lakes and 4,300 kilometers of streams exist in Yellowstone National Park, all which are classified as Outstanding Natural Resource Waters (Class I), meaning they must receive a very high level of protection against degradation.

More than three million people visit the park each year to engage in a wide range of recreational activities. Throughout the winter season (December–March), most park roads are closed to vehicular travel and are groomed and maintained for oversnow transportation. As a result, many visitors during winter months travel by snowmobiles. A significant increase in use of these machines was first documented in the late 1980s, when the numbers had increased nearly tenfold over that in 1968. By the mid-1990s the number of snowmobiles entering the park had increased to nearly 75,000 per year. During this time most snowmobiles had two-stroke engines, known to burn fuel inefficiently. Consequently, the steady increase in snowmobile use within the park was a concern to resource managers because of the potential that the increase in fossil-fuel combustion could result in greater levels of emissions entering the pristine surface waters of the park.

During late March through mid-April of 2003 and 2004 snowmelt runoff samples were collected from four sites along the heavily used road corridor between Yellowstone National Park's West Entrance at West Yellowstone, Montana, and the Old Faithful visitors area. Three of these sites were located immediately adjacent to the roadway in the vicinity of the West Entrance, Madison Junction, and Old Faithful. The remaining site was used as a control, located near Madison Junction approximately 100 meters from the roadway and away from the effects of snowmobiles. Each site was visited on 9–10 different days during the spring sampling period, with visits dependent on having a daily temperature >5oC and good potential to obtain snowmelt runoff. In situ water quality measurements (i.e., water temperature, dissolved oxygen, pH, specific conductance, and turbidity) were collected. Snowmelt runoff samples were analyzed for nine volatile organic compounds (VOCs), including benzene, ethylbenzene, ethyl tert-butyl ether, isopropyl ether, meta and para-xylene (m- and p-xylene), methyl tert-butyl ether, ortho-xylene (o-xylene), tert-pentyl methyl ether, and toluene. Of these nine compounds, only five were detected during any one sampling event. The detected compounds included benzene, ethylbenzene, m- and p-xylene, o-xylene, and toluene.

All in situ water quality measurements were within acceptable limits. The VOCs were most prevalent at the Old Faithful site, which receives extremely high use by snowmobiles each year. Fortunately, the concentrations of all VOCs detected each year were considerably below the U.S. Environmental

Protection Agency's (USEPA) water quality criteria and guidelines for VOCs targeted in this study. During the course of the study, VOC concentrations of snowmelt runoff in Yellowstone National Park were below levels that would adversely impact aquatic systems. However, future research in Yellowstone National Park on snowmobile emissions should address the potential for another group of harmful chemicals known as the polycyclic aromatic hydrocarbons (PAH). The PAH tend to be more capable of persisting in the environment for longer periods than VOCs and are suspected at the Old Faithful site as it received runoff from a paved parking area.

3. **Impacts of Two-Stroke Engines on Aquatic Resources.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 145-149. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Summary: Impacts to aquatic species that can be attributed to atmospheric deposition from snowmobiles have not been well studied. Field studies are extremely difficult to conduct because atmospheric deposition rates could be affected by numerous factors, including temperature, proximity to water, and combustion efficiency of individual snowmobiles. Tremendous uncertainty accompanies this topic with reference to affects on aquatic resources of the Greater Yellowstone Area.

In situations where snowmobiling occurs over open water, obvious impacts will include direct discharge into aquatic habitats. Appreciable contamination from emissions from backcountry snowmobiling probably occurs less frequently.

4. **Effects of Snowmobiling across Open Water on Fish and Wildlife.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 161-162. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Summary: Snowmobiling on open water involves a daring or, in some cases, intoxicated snowmobiler with a powerful machine who attempts to either make it across open water or to take a round trip on open water without submerging the snowmobile. Snowmobiling on open water has the potential to affect water quality; aquatic species, such as invertebrates and trout; and riparian-dependant wildlife, specifically moose, furbearers, waterfowl, and bald eagles.

Snowmobiling on open water has the potential to pollute the water with snowmobile exhaust and spilled oil and/or gas, to stir up sediments on the bottom, to disturb winter-stressed fish and other aquatic wildlife, and to displace wildlife from important winter habitat. A literature search produced little information on the effects of snowmobiling on open water.

Agency managers need to be aware of the potential for snowmobile use on open water and that there are possible effects to water quality, fish, and wildlife. This activity is in defiance of common sense, and agencies should prohibit it on public land to avoid impacts to water quality, aquatic species, and riparian-dependant wildlife.

5. **Effects of Snowmobile Use on Snowpack Chemistry in Yellowstone National Park, 1998.** Ingersoll, G.P. (1999) U.S. Department of the Interior – U.S. Geological Survey, Water-Resources Investigations Report 99-4148, prepared in cooperation with the National Park Service

Abstract: Snowmobile use in Yellowstone National Park has increased substantially in the past three decades. In areas of greatest snowmobile use, elevated levels of by-products of gasoline combustion such

as ammonium and benzene have been detected in snowpack samples. Annual snowpacks and snow-covered roadways trap deposition from local and regional atmospheric emissions.

Snowpack samples representing most of the winter precipitation were collected at about the time of maximum annual snow accumulation at a variety of locations in and near the park to observe the effects of a range of snowmobile traffic levels. Concentrations of organic and inorganic compounds in snow samples from pairs of sites located directly in and off snow-packed roadways used by snowmobiles were compared. Concentrations of ammonium were up to three times higher for the in-road snow compared to off-road snow for each pair of sites. Thus, concentrations decreased rapidly with distance from roadways. In addition, concentrations of ammonium, nitrate, sulfate, benzene, and toluene in snow were positively correlated with snowmobile use.

Patterns of Chemistry Relative to Snowmobile Use: Although clear patterns have emerged to establish ammonium and sulfate as reliable indicators of snowmobile emissions in nearby snowpacks, particularly along the corridor from West Yellowstone to Old Faithful, nitrate concentrations are not much influenced by these local effects. With the exception of the extreme exposure of the direct exhaust sample at Supply Forks, snowpack concentrations of nitrate were relatively unaffected by snowmobile traffic.

Siting off-road sampling sites 50 m from snowmobile routes seems adequate to eliminate contamination from snowmobiles and allow observation of regional effects. Comparisons between chemistries at the West Yellowstone sites 50 and 1,000 m off-road show similar values for all major ions and also are similar to background levels elsewhere in the Rocky Mountain region; therefore, contamination from snowmobiles is less likely 50 m from highway corridors, especially when compared to in-road chemistry. Furthermore, two sites 50 m off-road and a third site 1,000 m off-road around Old Faithful also had good agreement between major-ion concentrations and also were unaffected by snowmobile traffic, as shown by the in-road snow chemistry. Comparisons of these off-road and in-road sites in the Old Faithful area located within 2 to 3 km of the geyser also indicate negligible effects on sampling results from the geothermal activity.

Hydrocarbon levels in the snowpacks near snowmobile use were elevated relative to background snowpack chemistry in the study but were lower, in general, than concentrations at hundreds of locations nationwide representing a full spectrum of watershed settings ranging from subalpine to urban (Dennehy and others, 1998). Detectable concentrations of VOC's in Yellowstone ranged from 12.2 to 973 ng/L (table 5). VOC concentrations detected in urban storm water in the United States have been found to range from 200 to 10,000 ng/L, with more concentrated levels observed less frequently (Lopez and Bender, 1998; Lopez and Dionne, 1998). In a variety of urbanized, forested, and agricultural settings in New Jersey (Reiser and O'Brien, 1998), median concentrations of seven streams detected for benzene (60 ng/L), MTBE (420 ng/L), toluene (60 ng/L), and o-xylene (10 ng/L) were markedly higher than concentrations in snowmelt runoff at Yellowstone except for except for toluene (table 8). Little is known about levels of VOC's in Rocky Mountain snowpacks. Bruce and McMahon (1996) reported concentrations in snowfall collected in the Denver metropolitan area to be low.

Toluene concentrations in snowmelt runoff in Yellowstone (less than 25 to 252 ng/L; table 8) further indicate the potential sensitivity to contamination of snow and surface-water samples. Even at Loch Vale (table 4), the backcountry site in Colorado several kilometers from the nearest roadway, toluene concentrations were similar to those detected in the snowpacked roadway at Sylvan Lake (108 ng/L; table 5). Additionally, toluene concentrations in the snowpacked roadway at Old Faithful also were very similar to the concentration in snow 1 km off the highway (table 5). In some cases, there was a more clearly observable pattern, such as with comparisons between in-road and off-road sites at West Yellowstone and at the site 8 km east of West Yellowstone (West Yellowstone, 8 km east, table 5). The Tower Falls site, several kilometers from snowmobile traffic, had a low concentration (89.3 ng/L) similar to that detected in both the original (91.5 ng/L) and replicate (III ng/L) snow samples at Loch Vale, Colorado (table 4). Oddly, the snowmelt runoff grab sample from the area near Tower Falls contained the highest concentration of toluene (252 ng/L). Clearly, more investigation is needed to determine whether these anomalously high values for toluene (relative to benzene, MTBE, and xylenes) in snowmelt runoff are due to the sampling methodology, other sources of contamination, analytical techniques, or ambient conditions. In spite of these uncertainties, the toluene snow chemistry positively correlates with other hydrocarbon and major-ion concentrations.

Drinking-water standards for benzene (5,000 ng/L), toluene (1,000,000 ng/L), and xylenes (10,000,000 ng/L) published by the U.S. Environmental Protection Agency (1996) far exceed any levels detected in either snow or snowmelt runoff at Yellowstone in this study. A drinking-water standard for MTBE has not yet been determined, but future regulation is planned. Even the highest detections of benzene in snow (167 ng/L at in-road site 8 km east of West Yellowstone) or snowmelt (less than 10 ng/L at all sites), or toluene in snow (726 ng/L at in-road site 8 km east of West Yellowstone) or snowmelt (252 ng/L near Tower Falls) at Yellowstone are far less than the established standards for water consumed by humans (less than 4 percent and less than 1 percent, respectively).

<u>Conclusions:</u> Snowpack-chemical analyses for ammonium and sulfate have proven to be repeatable indicators of snowmobile use in Yellowstone National Park and in Colorado, and the hydrocarbons benzene, toluene, and xylenes correlate well with patterns observed in 1998 for ammonium and sulfate in the park. Concentrations of ammonium and sulfate at the sites in snowpacked roadways between West Yellowstone and Old Faithful were greater than those observed at any of 50 to 60 other snowpack-sampling sites in the Rocky Mountain region and clearly were linked to snowmobile operation. Concentrations of ammonium, sulfate, and hydrocarbon compounds found in gasoline correlate with snowmobile use and traffic levels; where traffic volumes per day were greater, so were chemical concentrations. Thus, these combined analyses of chemistry of Yellowstone snowpacks are good indicators of the effects of high or low snowmobile traffic levels in the park. These chemical data establish important baselines for future evaluations. Further, these results indicate that snowmobile use along the routes originating at the South and East Entrances, and not including the immediate area (within 1 km) surrounding Old Faithful, may not be substantially affecting atmospheric deposition of ammonium, sulfate, and hydrocarbons related to gasoline combustion.

Preliminary analyses of snowmelt-runoff chemistry from five of the snow-sampling sites indicate that elevated emission levels in snow along highway corridors generally are dispersed into surrounding watersheds at concentrations below levels likely to threaten human or ecosystem health. Localized, episodic acidification of aquatic ecosystems in these high snowmobile-traffic areas may be possible, but verification will require more detailed chemical analyses of snowmelt runoff.

WILDLIFE

A wide range of studies, dating back to the 1970s, have been done regarding the impacts of snowmobiles on wildlife. Generally, most studies have concluded that impacts are minimal or can at least be managed and that snowmobilers and wildlife can coexist very well and have done so for many years.

Even though many studies are twenty or thirty years old, their results are still applicable if not even substantially less (lower levels of impact) given the significant decrease in snowmobile sounds and exhaust emissions compared to 1970- and 1980-era snowmobiles. While most recent studies have been related to the Yellowstone National Park Winter Plan or to the growing ATV use (similar to the 'growing snowmobile use' that triggered many of the 1970s and 1980s era snowmobile studies), many have applicability and can be extrapolated for use in other areas. General snowmobile related findings include:

A University of Wisconsin study on the effects of snowmobile sound levels on deer and cottontail rabbits concluded that "only minor reactions were noted in the movements of cottontail rabbits and white-tailed deer to moderate and intensive snowmobiling activity" and that it had not been possible to determine sound levels at which there is a clear reaction on the part of the deer "because snowmobiles must be so close to deer to generate the higher levels that other factors such as visible presence…are likely to be more important." This study also compared the reaction of deer to the presence of cross-country skiers and found that when cross-country skiers replaced snowmobiles on the test trail systems, the deer moved away from the trail more frequently.

A study by the State of Maine concluded that, "Deer consistently bedded near snowmobile trails and fed along them even when those trails were used for snowmobiling several times daily. In addition, fresh deer tracks were repeatedly observed on snowmobile trails shortly after machines had passed by, indicating that deer were not driven from the vicinity of these trails." It also found that "the reaction of deer to a man walking differed markedly from their reaction to a man on a snowmobile. This decided tendency of deer to run with the approach of a human on foot, in contrast to their tendency to stay in sight when approached by a snowmobiler, suggests that deer responded to a machine and not to the person riding it."

A study conducted on the White Mountain National Forest in New Hampshire monitored snowmobile operations and deer movement and concluded that deer travel patterns were not affected by periodically heavy snowmobile use. In addition, continued use of established snowmobile trails was recommended.

The University of Minnesota study found no meaningful difference in deer's home range during periods of snowmobile use and non-use.

Addressing the subject of snowmobile operations in Yellowstone National Park, former Superintendent Jack Anderson commented, "We found that elk, bison, moose, even fawns, wouldn't move away unless a machine was stopped and a person started walking. As long as you stayed on a machine and the machine was running, they never paid any attention. If you stopped the machine, got off and started moving, that was a different story. The thing that seemed to be disturbing to them was a man walking on foot."

Voyageurs National Park reopened eleven bays located in the park to snowmobiling in 2001 as the result of a study that found there was no significant correlation between wolf activity and human use on these bays which had been closed to snowmobiling in 1992.

The Michigan DNR reported in 2005 that the gray wolf population in Michigan's Upper Peninsula (U.P.) rose from 360 to 400 this past year – hand-in-hand with the growth of snowmobiling in the U.P. – and that they were proposing to remove the wolf from the "endangered species" list. At the same time, the number of gray wolves in the Northern Rockies has surpassed 1,000 – just a decade after wolves were reintroduced to Yellowstone National Park – and concurrent with snowmobiling growth in the Rockies.

General and specific species-related wildlife studies related to snowmobiling or OHVs include:

General / Wildlife and Nature

1. **Effects of Recreation on Animals Revealed as Widespread through a Global Systematic Review**
   Larson CL, Reed SE, Merenlender AM, Crooks KR (2016)
   https://www.snowmobileinfo.org/snowmobile-access-docs/effects-of-recreation-on-animals-2016.pdf

Abstract: Outdoor recreation is typically assumed to be compatible with biodiversity conservation and is permitted in most protected areas worldwide. However, increasing numbers of studies are discovering negative effects of recreation on animals. We conducted a systematic review of the scientific literature and analyzed 274 articles on the effects of non-consumptive recreation on animals, across all geographic areas, taxonomic groups, and recreation activities. We quantified trends in publication rates and outlets, identified knowledge gaps, and assessed evidence for effects of recreation. Although publication rates are low and knowledge gaps remain, the evidence was clear with over 93% of reviewed articles documenting at least one effect of recreation on animals, the majority of which (59%) were classified as negative effects. Most articles focused on mammals (42% of articles) or birds (37%), locations in North America (37.7%) or Europe (26.6%), and individual-level responses (49%). Meanwhile, studies of amphibians, reptiles, and fish, locations in South America, Asia, and Africa, and responses at the population and community levels are lacking. Although responses are likely to be species-specific in many cases, some taxonomic groups (e.g., raptors, shorebirds, ungulates, and corals) had greater evidence for an effect of recreation. Counter to public perception, non-motorized activities had more evidence for a negative effect of recreation than motorized activities, with effects observed 1.2 times more frequently. Snow-based activities had more evidence for an effect than other types of recreation, with effects observed 1.3 times more frequently. Protecting biodiversity from potentially harmful effects of recreation is a primary concern for conservation planners and land managers who face increases in park visitation rates; accordingly, there is demand for science-based information to help solve these dilemmas.

2. **Comparability Assessment of Snowmobile and Snowcoach Transportation Event Impacts to Park Resources and Values and the Visitor Experience.** Yellowstone National Park Winter Use Plan – Supplemental Environmental Impact Statement, Appendix A **(**February 2013) National Park Service
   https://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

See #1 in the Air Quality section.

3. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2009 Annual Report**. McClure, C., Reinhart, D., White, P.J., Donovan, M. & Teets, B. (2009) National Park Service, Yellowstone Center for Resources. http://www.nps.gov/yell/parkmgmt/upload/Winter%202008-2009%20Wildlife%20Monitoring%20Report%20Draft.pdf

Executive Summary: Staff from the Yellowstone Center for Resources monitored wildlife responses to motorized winter recreation during December 10, 2008 through March 22, 2009. Oversnow vehicle traffic and general park visitation was lower this winter than the winter of 2007-2008 with a 28% drop in snowmobiles and a 10% drop in snowcoaches.

We used snowmobiles to conduct repeated surveys of wildlife responses to motorized winter vehicles and human activities along three groomed road segments in areas of both low and high intensity human and wildlife use. Our sampling unit was the interaction between oversnow vehicles and an observed group of wildlife within 500 meters (547 yards) of the road. We focused our efforts on monitoring the responses of bison, elk, and trumpeter swans owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter.

The behaviors of humans traveling in oversnow vehicles in response to observing wildlife groups were as follows: 55% demonstrated no visible reaction; 33% stopped; 6% dismounted their vehicles; 5% approached wildlife; and 1% impeded or hastened wildlife on the roadway. Seventy-five percent of the wildlife showed no visible response to oversnow vehicle interactions, 18% looked at the oversnow vehicles or humans and resumed their previous activity, 1% traveled, 5% displayed alarm or attention and less than 1% fled from the area.

4. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2008 Annual Report**. McClure, C., Davis, T., Reinhart, D. & White. P.J. (2008) National Park Service, Yellowstone Center for Resources. http://www.nps.gov/yell/parkmgmt/upload/2008wildlife_final.pdf

Executive Summary: Staff from the Yellowstone Center for Resources monitored wildlife responses to motorized winter recreation during December 14, 2007 through March 24, 2008. Oversnow vehicle traffic by visitors was slightly lower than winter 2006-07. This primarily reflected a 7% drop in snowmobiles. However, the park saw a 9% increase in snowcoaches during 2007-08.

We used snowmobiles to conduct repeated surveys of wildlife responses to motorized winter vehicles and human activities along three groomed road segments in areas of both low and high intensity human and wildlife use. Our sampling unit was the interaction between oversnow vehicles and an observed group of wildlife within 500 meters (547 yards) of the road. We focused our efforts on monitoring the responses of bison, elk, and trumpeter swans owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter.

The behaviors of humans traveling in oversnow vehicles in response to observing wildlife groups were as follows: 52% demonstrated no visible reaction; 38% stopped; 4% dismounted their vehicles; 5% approached wildlife; and 1% impeded or hastened wildlife on the roadway. Seventy-two percent of the wildlife showed no visible response to oversnow vehicle interactions, 20% looked at the oversnow vehicles or humans and resumed their previous activity, 4% traveled, 4% displayed alarm or attention and less than 1% fled from the area.

5. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2007 Annual Report**. Davis, T., White. P. J., Reinhart, D. & McClure, C. (2007) National Park Service, Yellowstone Center for Resources. http://www.nps.gov/yell/parkmgmt/upload/2007winusewildliferpt_final.pdf

Executive Summary: Staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office monitored wildlife responses to motorized winter recreation during December 18, 2006 through March 29, 2007. The winter of 2006-07 was moderate in terms of snow pack and temperatures. Over-snow vehicle traffic by visitors was slightly higher than in winter 2005-06, but low in comparison to previous winters.

We used snowmobiles to conduct repeated surveys of wildlife responses to motorized winter vehicles and human activities along four groomed road segments in areas of both low and high intensity human and wildlife use. Our sampling unit was the interaction between over-snow vehicles and an observed group of wildlife within 500 meters (547 yards) of the road. We focused our efforts on monitoring the responses of bison, elk, and trumpeter swans owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter.

The behaviors of humans traveling in over-snow vehicles in response to observing wildlife groups were as follows: 57% demonstrated no visible reaction; 32% stopped; 7% dismounted their vehicles; 2% approached wildlife; and 2% impeded or hastened wildlife on the roadway.

We suggest that training for guides, park staff, and concessionaires include the following recommendations: 1) stop at distances >100 meters (109 yards) from groups of wildlife, when possible; 2) reduce the frequency of multiple groups of motorized vehicles stopping in the same area to observe wildlife; 3) reduce the number of stops to observe wildlife and, 4) reduce human activities away from vehicles during these stops.

6. **Behavioral Responses of Wildlife to Snowmobiles and Coaches in Yellowstone.** White, P.J., Davis, T., Borkowski, J.J., Garrott, R.A., Reinhart, D.P., & McClure, D.C. (2006) Yellowstone National Park and Montana State University, Bozeman, Montana. http://www.nps.gov/yell/parkmgmt/upload/2006wildliferpt_final.pdf

Abstract: Managers of Yellowstone National Park are charged with protecting some of our nation's most important natural resources, while providing for their use and enjoyment by visitors. Over 100,000 visitors entered the park by over-snow, motorized means on snowmobiles (94%) or coaches (6%) during 2003-2006. Most vehicles toured the central portion of the park where bald eagles (Haliaeetus leucocephalus), bison (Bison bison), coyotes (Canis latrans), elk (Cervus elaphus), and trumpeter swans (Olor buccinator) wintered in areas close to roads. We sampled 5,688 interactions between groups of these species and groups of snowmobiles and coaches during 2003-2006 and used multinomial logits models, odds ratios, and predicted probabilities to identify conditions leading to behavioral responses. Bison responded less frequently (20%) to snowmobiles and coaches than swans (43%), elk (52%), coyotes (61%), or bald eagles (83%) due to fewer vigilance responses. However, the frequency of higher-intensity movement responses was similar among species (8-10%), with the exception of coyotes (24%). The likelihood of vigilance and movement responses by these species increased significantly if animals were on or near roads, animals groups were smaller, humans approached animals on foot, interaction time increased, or the numbers of snowmobiles and coaches in a group increased. There were thresholds on the odds of eliciting a response by wildlife for several of these covariates. We did not detect significant increases or decreases in the odds of movement responses for any wildlife species as cumulative over-snow vehicle traffic increased through the winter. However, the likelihood of a vigilance response by bison decreased within the winter having the largest visitation, suggesting some habituation to snowmobiles and coaches. In contrast, there was a significant increase in the odds of vigilance responses by elk as the cumulative visitation increased through the winter. Human disturbance did not appear to be a primary factor influencing the distribution and movements of the wildlife species we studied. The risk of vehicle-related mortality from snowmobiles was quite low and observed behavioral responses were apparently short-term changes that were later reversed. Bison, elk, and swans in Yellowstone used the same core winter ranges during the past three decades despite large winter-to-winter variability in cumulative exposure to OSVs. There was no evidence that snowmobile use during the past 35 years adversely affected the demography or population dynamics of bald eagles, bison, elk, or trumpeter swans (no data was available for coyotes). Thus, we suggest regulations restricting levels and travel routes of OSVs were effective at reducing disturbances to these wildlife species below a level that would cause measurable fitness effects. We recommend park managers consider maintaining OSV traffic levels at or below those observed during our study. Regardless, differing interpretations of the behavioral and physiological response data will continue to exist because of the diverse values and beliefs of the many constituencies of Yellowstone.

7. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2005 Annual Report**. White, P.J., Davis, T., & Borkowski, J. (2005) National Park Service, Yellowstone Center for Resources & Montana State University. http://www.nps.gov/yell/parkmgmt/upload/winterrec05.pdf

Abstract: This study monitored the behavioral responses of bison (*Bison bison*), elk (*Cervus elaphus*), and trumpeter swans (*Olor buccinator*) to motorized winter recreation by repeatedly surveying seven groomed or plowed road segments in Yellowstone National Park during December 2004 through March 20005. The study sampled >2,100 interactions between vehicles and wildlife groups and used multinominal logits models to identify conditions leading to behavioral responses. Responses by these wildlife species to over-snow vehicles were relatively infrequent, short in duration, and of minor to moderate intensity, with >81% categorized as no apparent response or look/resume activities, 9% attention/alarm, 7% travel, and 3% flight or defense. Analyses of similar data collected during 1999-2004 indicated the likelihood of active responses by wildlife increased significantly if (1) wildlife were on or near roads, (2) more vehicles were in a group, (3) wildlife groups were smaller, (4) ungulates were in meadows instead of forest or geothermal habitats, (5) interaction times increased, (6) wildlife were traveling instead of resting, and (7) humans dismounted vehicles and/or approached wildlife. The likelihood of an active response by bison or elk decreased as cumulative visitation increased, suggesting that these ungulates habituated somewhat to motorized recreation. There was no evidence of population-level effects to ungulates from motorized winter use because estimates of abundance either increased or remained relatively stable during three decades of motorized recreation prior to wolf colonization in 1998. Thus, **we suggest that the debate regarding the effects of motorized recreation on wildlife is largely a social issue as opposed to a wildlife management issue**. The likelihood of active responses by wildlife can be diminished by (1) restricting travel to predictable routes and times, (2) reducing the number of vehicles in groups, (3) reducing the number and length of stops to observe wildlife, (4) stopping vehicles at distances >100 meters, and (5) preventing human activities away from vehicles.

8. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2004 Annual Report**. White, P.J., Davis, T., & Borkowski, J. (2004) National Park Service, Yellowstone Center for Resources & Montana State University. http://www.nps.gov/yell/parkmgmt/upload/wildlifewinteruse_2004_final.pdf

Executive Summary: Staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office monitored the behavioral responses of wildlife to motorized winter recreation during December 12, 2003 through April 1, 2004, for comparison to data from previous and future winters. We used snowmobiles and wheeled vehicles to conduct repeated surveys of wildlife responses to motorized winter use vehicles and human activities along nine groomed or plowed road segments. Our sampling unit was the interaction between motorized winter use and an observed group of wildlife within 500 meters of the road. We focused our monitoring on the responses of bison, elk, and trumpeter swans to motorized winter use vehicles owing to the proximity and/or perceived sensitivity of these species to motorized vehicles during winter.

Snow pack during early winter (i.e., October and November of 2003) was less than the historic average since 1981. Snow pack was approximately average by late winter, however, with the exception of the northern range area where snow pack remained below average throughout the winter. There was relatively low motorized use by visitors during winter 2004, compared to previous winters. Approximately 16,000 "over-the-snow" vehicles (i.e., snowmobiles and snow coaches; OSVs) entered the park's west entrance during winter 2004, compared to >22,000 OSVs during winter 2003 (which was also a relatively low visitation winter owing to poor snow pack). This lower visitation resulted, in part, from court orders in December and February and the accompanying uncertainty imposed on motorized recreation in the park.

Similar to previous winters since 1999, the responses of most wildlife species to OSVs and associated humans during winter 2004 were typically minor, with 58% (n = 1,296) of the 2,239 total observed wildlife responses categorized as no apparent response, 18% (n = 410) look/resume, 11% (n = 252) attention/alarm, 9% (n = 196) travel, 4% (n = 82) flight, and <1% (n = 3) defense. Wildlife responses to motorized winter use were consistent across species (bison, elk, swans), but the magnitude of the responses varied considerably among species. The likelihood of observing an active response to snow coaches or increasing numbers of snowmobiles in a group was similar for bison and swans, but significantly higher for elk. The likelihood of a response by each species decreased as distance from the road increased. The estimated odds of observing an active response compared to no response by bison or elk were significantly higher for administrative traffic than for guided OSVs. Also, wheeled vehicles elicited substantially fewer active responses by bison or elk than either administrative or guided groups of OSVs.

Independent studies of the responses of wildlife to OSVs and associated humans in Yellowstone National Park (Hardy 2001, Jaffe et al. 2002, Davis et al. 2004) during 1999-2004 have consistently reported that behavioral responses were relatively infrequent, short in duration, and of low intensity. Also, bison and elk were less likely to respond on days with higher traffic, likely due to some sort of habituation to the relatively continuous traffic. Gross estimates of the additional energy costs of travel or flight responses provoked by OSVs were relatively moderate for elk. Thus, animals exposed to OSVs likely do not incur a substantial energetic cost from such interactions, and these costs are likely easily compensated for without any significant demographic consequences. These findings are supported by trends in the abundance of bison and elk populations since the onset of motorized winter use in Yellowstone National Park, which provide no evidence of population-level effects to ungulates from motorized winter use because their abundances either increased or remained relatively stable prior to wolf restoration. Thus, any adverse effects of motorized winter use to ungulates have apparently been compensated for at the population level.

Bison were observed on groomed roads during 311 of 2,597 observations of bison groups from December 12, 2003, through April 1, 2004. Thus, the vast majority of observed bison groups were using areas off the groomed roads, as has also been noted in previous winters. We are currently collaborating with researchers from Montana State University (Robert Garrott and John Borkowski) and California State University-Monterey Bay (Fred Watson and Susan Alexander) to analyze bison distribution and use of groomed roads during 1997-2004. We have also developed conceptual models of bison movement through the park based on remotely sensed landscape features (e.g., vegetation, terrain, and geothermal maps), snow pack measurements and modeling, and bison distribution data. These models have been used to predict bison trail systems and movements based on environmental constraints, which we intend to compare with the existing groomed road system to evaluate how grooming has affected bison movements. Draft reports of these analyses should be available in autumn 2004 or winter 2005.

Monitoring results during the winters of 2003 and 2004 suggest that several aspects of human behavior associated with motorized winter use could be modified through adaptive management to lessen the frequency of possible disturbances to wildlife. We recommend that training for guides, park staff, and concessionaires include the following voluntary recommendations: 1) stop at distances >100 meters from groups of wildlife, when possible; 2) reduce the frequency of multiple groups of motorized vehicles stopping in the same area to observe wildlife (i.e., reduce group size of motorized vehicles); 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops; and 4) reduce interaction time because the likelihood of an active response by wildlife increases with longer interaction times. This training is essential because recreationalists often perceive that it is acceptable to approach wildlife more closely than empirical data indicates wildlife will tolerate (Taylor and Knight 2003). Because bison and elk behaviorally respond to people deviating from known, predictable routes, management measures that encourage visitors to stay on roads and established trails should also reduce wildlife disturbance rates.

It is unlikely that significant changes in behavioral responses or population-level effects in response to OSVs will be detected in the near future owing to the dominating effects of winter severity, predator off-take (including restored wolves), and human removals on the behavior and demographics of these populations. Thus, we recommend some substantive changes in the focus of winter use monitoring for wildlife during winter 2005. First, we recommend focusing the behavioral sampling of wildlife responses to OSVs in the Madison-Firehole drainages, while ceasing such monitoring throughout the remainder of the park. This approach will enable us to maintain continuity in behavioral sampling in the area of most intensive OSV use, while providing us to with more logistical flexibility to begin focusing other issues of importance. Second, we recommend using field crews to sample and map bison travel vectors (i.e., trail systems) in the west-central portion of the park. These data can be used to validate the predictions of conceptual models of bison movement through the park based on remotely sensed landscape features (e.g., vegetation, terrain, and geothermal maps), snow pack measurements and modeling, and bison distribution data. If the models predict bison trail systems and movements accurately, then we can compare model predictions of bison movement based on based on environmental constraints with the existing groomed road system to evaluate how grooming has affected bison movements. Third, we recommend the collection of snow-urine samples from northern and central Yellowstone ungulates to assess nutrition using the methodology described by Pils (1997). This information will enable us to better assess energetic costs and physiological consequences of various environmental conditions, interactions with OSVs, and road grooming.

In collaboration with professors from Montana State University, we are currently analyzing the combined data set collected by various researchers during 1999-2004 regarding wildlife responses to motorized winter use in Yellowstone National Park. The objectives of these analyses are to evaluate potential indicator variables of wildlife responses to human winter use, identify key conditions leading to responses, quantify variations in the frequencies of responses, and estimate thresholds for the most important disturbance factors. When data is pooled from multiple winter seasons, we will: 1) improve the likelihood of detecting any potential effects that truly exist, but currently cannot be detected from a single season's data; 2) strengthen the evidence for those effects already statistically significant; and 3) eliminate any spurious effects that may be marginally significant in any particular winter. Thus, we expect to have a more thorough and rigorous analysis of the behavioral responses of wildlife to OSVs completed by winter 2005.

9. **Wildlife Responses to Motorized Winter Recreation in Yellowstone – 2003 Annual Report**. Davis, T., White, P.J., Borkowski, J., Reinhart, D., McClure, C., Perotti, P., McEneaney, T., Plumb, G., Smith, D. & wallen, R. (2003) National Park Service, Yellowstone Center for Resources & Montana State University. http://www.nps.gov/yell/parkmgmt/upload/motorizedwinterrec03.pdf

Executive Summary: Staff from the Yellowstone Center for Resources and Resource Management & Visitor Protection Office monitored wildlife responses to motorized winter recreation during December 16, 2002 through April 18, 2003. The purpose of this monitoring was to collect baseline information on existing conditions for comparison to data collected after the implementation of changes in winter use management during winter 2004. Such comparisons will enable us to evaluate the effectiveness of changes in management at attaining desired conditions.

The winter of 2003 was relatively mild in terms of snow pack and temperatures. As a result, visitor over-the-snow vehicle traffic was relatively low in comparison to previous winters. We used snowmobiles and wheeled vehicles to conduct repeated surveys of wildlife responses to motorized winter use vehicles and human activities along eight groomed or plowed road segments in areas of both low and high intensity human and wildlife use. Our sampling unit was the interaction between motorized winter use and an observed group of wildlife within 500 meters of the road. We focused our efforts on monitoring the responses of bison, elk, and trumpeter swans to motorized winter use vehicles owing to the proximity and/or perceived sensitivity of these species to motorized recreation activities during winter.

Overall, the responses of wildlife to over-the-snow vehicles and associated humans was typically minor, with 61% of the observed responses by groups of bison, elk, and swans categorized as no apparent response, 23% look/resume, 5% attention/alarm, 8% travel, 2% flight, and 1% defense. Wildlife responses to motorized winter use were species dependent and the likelihood of observing an active response by bison and swans (but not for elk) increased as the numbers of snowmobiles in a group increased. Also, the likelihood of observing an active response by elk and swans (but not for bison) increased as the numbers of snow coaches in a group increased. The likelihood of a response by each species decreased as distance from the road increased.

Trends in the abundance of bison and elk populations since the onset of motorized winter use in Yellowstone National Park provide no evidence of population-level effects to ungulates from motorized winter use, with the abundance of bison and elk either increasing or remaining relatively stable prior to wolf restoration. Thus, any adverse effects of motorized winter use to ungulates have apparently been compensated for at the population level.

Based on monitoring results during winter 2003, we recommend that training for guides, park staff, and concessionaires include the following voluntary recommendations: 1) stop at distances >100 meters from groups of wildlife, when possible; 2) reduce the frequency of multiple groups of motorized vehicles stopping in the same area to observe wildlife; and 3) reduce the number of stops to observe wildlife and human activities away from vehicles during these stops. We are currently analyzing data collected during 1999-2003 to evaluate potential indicator variables of wildlife responses to human winter use, identify key conditions leading to responses, quantify variations in the frequencies of responses, and estimate thresholds for important disturbance factors. These analyses should help us refine our recommendations for adaptive management of motorized winter use to minimize the frequency of possible disturbances to wildlife.

The following paragraphs contain additional information our monitoring efforts during winter 2003. For a more detailed presentation, we suggest that the reader review Chapter I (Introduction) and Chapter III (Results). Additional information regarding our methods and discussion of our findings is provided in Chapter II (Methods) and Chapter IV (Discussion). Recommendations for adaptive management and improving the monitoring protocol during future winters are presented in Chapter V (Recommendations).

Synopsis of Findings:
In general, average snow water equivalents (i.e., the amount of water in the snow) per month were lower than the overall monthly averages since 1981. For example, the cumulative snow water equivalent value of 4,999 centimeters at the Madison Plateau SNOTEL site during winter 2003 was lower than totals obtained during 28 of the past 36 winters at this site. Similarly, ambient temperatures during winter 2003 were relatively moderate for ungulates. Only one day had a minimum temperature below the approximate effective critical temperature for bison (i.e., -34F), and <12% of total days were less than the approximate effective critical temperature for elk (i.e., 0F).

The number of snowmobiles entering the West Entrance Station exceeded 550 machines, which is the daily snowmobile entry limit for the winters of 2004 and 2005, on only one day. The numbers of snowmobiles entering the South and East Entrance Stations during winter 2003 did not exceed the daily snowmobile entry limits for each station during the winters of 2004 and 2005 (i.e., South = 250 snowmobiles; East = 100 snowmobiles). The cumulative total of over-the-snow vehicles entering the West Entrance Station surpassed 7,500 vehicles on January 20th during winter 2003. In contrast, this threshold was reached on December 31st during the winters of 1999 and 2000.

During daylight hours, observers traveled until a wildlife group (i.e., $\geq$1 animal) was detected within 500 meters of the road. The observers remained in a position along the road to observe the group until $\geq$1 motorized winter vehicle (i.e., snowmobile, snow coach, wheeled vehicle) entered a zone within 500 meters of the group. The observers categorized the motorized vehicle/human activity and associated wildlife response during a single interaction (i.e., one group of vehicles and the response by the group of wildlife) and then continued the survey to locate the next group of wildlife along the road segment. The observers categorized the highest level of human activity (i.e., most potential for disturbance) and predominant response behavior of the majority of the animals in the group during interactions. Winter use crews conducted 332 surveys of road segments, covering 11,182 kilometers. Observers recorded 4,269 groups of wildlife during these surveys, including 908 groups of elk, 2,294 groups of bison, 447 groups of swans, and 620 groups of other species (e.g., bald eagles, coyotes, wolves). Observers recorded human behaviors and the responses of wildlife to motorized winter vehicles during 3,020 interactions. No groups of wildlife were observed during 30 surveys of road segments.

The behavior of over-the-snow vehicles and associated humans in response to wildlife groups was typically minor, with 59% of the 1,315 total observed human behaviors to groups of bison, elk, and swans categorized as no visible reaction to wildlife, 5% stop/resume, 13% stop and observe for an extended period, 13% dismount over-the-snow vehicles, 8% approach wildlife, 1% impede and/or hasten wildlife, and 1% undetermined. Qualitative comparisons suggest that the behaviors of visitors were similar between low and high intensity use areas, and those associated with snowmobiles or snow coaches. There appeared to be a tendency for visitors in commercially guided snowmobile groups to approach wildlife more frequently than visitors in unguided snowmobile groups. This apparent difference may be misleading or nonexistent, however, owing to the relatively small sample of guided groups compared to unguided groups. Additional data from one or more winter seasons will be necessary to establish the reliability of these apparent differences.

Bison rarely responded to human activity along roads (22% of interactions), whereas elk and swans responded more often ($\leq$58% of interactions). Behavioral responses of wildlife decreased as distance from motorized winter use corridors increased. The estimated odds of observing no response relative to either a look and resume or active response by bison, elk, and swans was significantly higher for each 100 meter increase in distance from the road. Also, mean distances of bison and elk groups from groomed road segments during winter 2003 did not indicate avoidance of the road as motorized use increased (as indicated by daily over-the-snow vehicle traffic entering the West Entrance Station). In combination with the relatively minor and infrequent responses by wildlife to over-the-snow vehicle traffic, these results suggest that wildlife habituated to motorized winter use.

Wildlife responses varied by species among commercially guided, unguided, and administrative groups during winter 2003. For example, the estimated odds of observing an active response relative to no response by bison were significantly higher for a commercially guided group than for an unguided group (under identical conditions). Conversely, the estimated odds of observing a look and resume response or an active response relative to no response by elk was significantly lower for a commercially guided group than for an unguided group. There were no statistically significant results among comparisons of swan responses to commercially guided, unguided, and administrative groups. We suspect that these somewhat inexplicable variations in associations among wildlife responses and guide status results from the relatively low sample of guided groups (<10% of cases) compared to unguided groups. Thus, these apparent differences must be viewed cautiously because they may be misleading or nonexistent. By collecting data over several winter seasons, we can reexamine this issue with an increased sample size to establish the reliability of these apparent differences.

Statistical analyses by Dr. Borkowski indicated that several other variables likely influence the odds of a response by bison, elk, and/or swans to motorized winter use. These variables include group size, habitat type, precipitation, visibility, wildlife activity (e.g., standing v. bedded), ambient temperature, interaction time, and daily numbers of motorized vehicles entering the south and west gates. For example, for each 10-animal increase in the size of a wildlife group during winter 2003, the estimated odds of observing no response relative to a look and resume response were significantly higher for both bison and elk. By collecting data over several winter seasons, the influence of these variables on wildlife responses can be reexamined with an increased sample size, thereby providing better inference.

Bison were observed on groomed roads during 159 of 1,668 observations of bison groups from December 27, 2002, through March 10, 2003. Thus, the vast majority of observed bison groups were using areas off the groomed roads. One hundred and twenty of the bison groups observed on groomed roads were traveling, whereas 36 groups were stationary and 3 groups were resting. The estimated odds of observing an active response relative to no response was 20 times greater when bison were on the road than when they were off the road. Bison use of groomed roads occurred throughout the daylight survey hours, with no apparent peak time of road use. Elk groups were observed using groomed roads less than bison.

A total of 95 interaction events between ungulates and over-the-snow vehicles and associated humans were documented when animal groups were on the groomed roads, including 75 groups of snowmobiles and 20 groups of snow coaches. Thirteen percent of these snowmobile groups impeded or hastened wildlife movement. Twenty-five percent of these snow coach groups impeded or hastened wildlife movement. Wildlife were observed on the plowed road from Mammoth to the Northeast Entrance on 35 occasions during our surveys, including 14 bison groups, 16 coyote groups, and 5 elk groups. Wildlife were not trapped by, or forced to jump over, snow berms along the sides of the road during any of these observations.

Counts of trumpeter swans on the north and west shores of Yellowstone Lake and along the Yellowstone River peaked in late November at 496 swans, and decreased relatively consistently through late February as open water sections of the Yellowstone River diminished. Conversely, counts of trumpeter swans along the Madison and Firehole Rivers increased during late December, peaked at 47 swans in mid-January, and remained relatively high through early February. As the winter progressed, and open water areas in the park diminished, the proportion of the swan population counted within Yellowstone National Park decreased compared to areas outside the park. Thus, relatively fewer swans were exposed to motorized winter use in the park.

The collection of fecal samples and measurement of fecal glucocorticoid levels via radioimmunoassay has been shown to be an effective, non-invasive method to measure physiological stress in elk. We collaborated with Dr. Robert Garrott, Montana State University, to collect fecal samples (105 total) at approximately 2-week intervals throughout the winter from 35 radiocollared adult female elk in the west-central portion of the park. We have contracted with Drs. Robert Garrott and Scott Creel, Montana State University, to extract the fecal samples and determine nanograms of corticosterone excreted per gram of dry feces using the double-antibody [125I] corticosterone radioimmunoassays. These analyses should be completed during 2004. The results of the analyses will be compared to similar samples collected during winters of 1999 and 2000 to evaluate the potential for chronic stress of ungulates in areas with relatively intensive motorized winter use.

10. **Wildlife Road Survey and Human Interactions On and Off Road: Final Report**. Jaffe, R., Elwood, D., Dimmick, A., Davis, T, & McClure, C. (2003) Yellowstone National Park – West District Resource Management.

Introduction: Studies were conducted in Yellowstone National Park to examine the effects of winter recreation on wildlife by Aune (1981) and Hardy (2001), and the effects of road grooming on bison by Bjornlie and Garrott (2001). Monitoring wintering wildlife distribution and wildlife-human interactions along the road corridor between West Yellowstone and Old Faithful was initiated during the 2001-2002 winter as part of the effort to reduce resource impacts and improve visitor safety and enjoyment in Yellowstone National Park. Methods from Hardy (2001) were expanded so this year's monitoring could be compared to results from her study.

Three biological technicians were hired for winter monitoring efforts beginning on December 11. The first three weeks were used for training, protocol testing, and project development. A total of 170 road surveys were conducted on 74 days, December 27 through March 10, with an average duration of 2.4 hours and 3,498 wildlife groups documented, and a total of 510 site-specific human-wildlife interaction events were recorded during the study. Staff logged over 9,000 miles on two snowmobiles. The two primary objectives of these surveys were to (1) document seasonal and diurnal wildlife distribution and activity, and (2) document human behavior in relation to wildlife and wildlife responses to human behavior associated with snowmobile and snowcoach use.

Results: The total number of animals counted during road surveys was 25,173. Bison, elk, swans, bald eagles, and coyotes were the most numerous species counted and are summarized below. Less common species sighted during surveys, which included moose, mule deer, muskrat, wolf, golden eagle, and double-crested cormorant, were excluded from the summary tables.

Eighty-seven percent (n=21,936) of the total number of animals observed during road surveys has no visible response to over-snow vehicles (OSVs). Of the 13% (n=3,263) of total animals counted that exhibited an observable response, 68% looked directly at the people viewing them and resumed their activity. Thirty-two percent of the responses were more active, including walk/swim away, rise from bed, attention/alarm, flight, agitate (buck, kick, bison tail-raise), jump snow berm, and charge. Of the 17,209 animals counted within 100m of the road, 17% (n=2,966) showed an observable response to the presence of OSVs that stopped, while 3% (n=297) of 7,924 animals counted further than 100m from the road showed a visible response

11. **Record of the Snowmobile Effects on Wildlife: Monitoring Protocols Workshop, Volume One.** Graves, T. & Reams, V. (2001) National Park Service – Biological Resource Management Division.

Abstract: This workshop included experts from federal agencies, state agencies, and universities and was held in Denver, Colorado on April 10-12, 2001 to summarize the state-of-science on monitoring the effects of snowmobiles on wildlife in national parks and surrounding lands. Volume 1 summarizes: 1) the presentations made during the plenary session of the workshop, 2) results of the electronic survey, 3) discussions and conclusions of the work groups, and 4) research recommendations. Discussion and Conclusions from this workshop include:

Primary Issues and Species: The primary issues raised in this study naturally pertained to wildlife impacts. The large majority of these issues related to immediate individual-level effects such as increased energy expenditure or behavioral changes. Concerns about snowmobile impacts on denning animals were also a significant issue. However, many of the wildlife issues raised dealt with larger-scale, complex processes, such as the indirect effects snowmobile use might have through its effects on predators or moving populations of animals into different territories.

The primary species of concern were carnivores, especially lynx, wolverines, and wolves. It is important to remember that respondents to this research were drawn from across the United States, and generally responded pertaining to the species with which they work. Therefore, the relative importance of each guild and species is certainly influenced by the people who chose to participate.

Conclusions about monitoring: The wide range of information needs identified by experts in the field present a significant challenge to those attempting to develop a uniform package of possible monitoring techniques. Information needs to appear to be guild or species-specific.

Respondents generally feel that population-level effects are most important or useful to study, followed by individual behavioral effects. The primary exception to this is for threatened or endangered species; respondents apparently believe that identifying any adverse individual level effects would be sufficient grounds for making management decisions. Unfortunately, it appears that most of the limited evidence available to date pertains to individual effects; a significant need therefore exists for basic research and monitoring of population-level effects.

Need for Monitoring or Need for Basic Research: Experts in the field of wildlife (and wildlife reactions to disturbance) are uncomfortable passing judgments on whether snowmobiles adversely (or, for that matter, positively) affect wildlife. Even under circumstance with the best available information, the question of when an impact becomes serious enough to warrant taking action is a subjective value judgment, and many respondents recognized this. But the majority felt that insufficient data exist to even begin to understand the issue. Only for ungulates are some scientists willing to say data are adequate, but even for these commonly studied species, most respondents have serious concerns.

This raises the question about whether monitoring is the place to focus agency efforts. Clearly, more basic research is needed. It is difficult to know what the best monitoring protocols would be when it is not clear about what effects should be monitored. Nevertheless, the NPS is under a mandate to develop monitoring protocols, and we feel it is important to begin monitoring, however basic, as early as possible. Too often monitoring is left until problems become severe; at that point it is quite difficult to discern the extent to which conditions have changed in the absence of baseline data. Therefore, we encourage researchers and managers to move forward with the development of monitoring protocols, and to continue to refine them as more information becomes warranted.

12. **Review of Research Related to the Environmental Impact Statement for the Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr. Memorial Parkway.** (2000) University of Wyoming, Institute of Environment and Natural Resources; p 3-17. http://wyotrails.state.wy.us/pdf/review.pdf

<u>Executive Summary:</u> Wildlife and Winter Recreation in Yellowstone National Park Studies – Unlike most of the reports reviewed in this document, the major report on wildlife issues does not represent a collection and analysis of data, but rather it is an extensive review of current literature (Oliff et al, 1999) on the effects of winter recreation on wildlife in the Greater Yellowstone Area. The Kurz report (1998) on bison in the Hayden Valley of Yellowstone, however, does follow the format of the other reports, that is, in the collection and presentation of data. In general, both reports offer valuable insights into the impact of winter use on the wildlife of Yellowstone. In the development of park management policies, however, it would be helpful either to conduct or to examine further studies, with more data on specific management questions. For example, it would be useful to identify, over time, critical habitat for the various sensitive species. And given the fact that wildlife may be particularly sensitive to weather and

climate conditions--which change over the course of time--, on-going monitoring would be extremely useful.

13. **Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment.** Olliff, T., Legg, K. & Kaeding, B. (1999) Greater Yellowstone Coordinating Committee, Yellowstone National Park. 303 p. http://atfiles.org/files/pdf/wildlife-winter-yellowstone.pdf or http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Summary: This publication is a compilation of papers submitted by resource managers and biologists in the Greater Yellowstone Area from the Forest Service, Park Service, the states of Montana, Idaho, and Wyoming, and private organizations. The chapters cover bighorn sheep, bison, elk, gray wolves, grizzly bears, lynx, mid-sized carnivores, moose, mountain goats, subnivean fauna, bald eagles, trumpeter swans, and vegetation. The purpose of this document is to provide guidelines for managing winter recreational use in the context of preserving wildlife populations. Several topics are discussed, including the current population status and trend of the individual species, relevant life history data, information on winter habitat use, summaries of studies on the influence of human activities on individual species in the winter, and the potential effects of specific winter recreational uses on those species.

14. **Winter Recreation Effects on Wildlife.** Caslick, J. & E. (1997) Natural Resources YCR, Yellowstone National Park.

Abstract: Numerous studies have concluded that wildlife is a major component of the Yellowstone experience, and a major economic "draw" to the area. As increasing pressures for development of visitor facilities and new modes of transportation evolve, early consideration of their potential effects on wildlife (including individual animals, animal populations, and associated ecological processes) become ever more important, if wildlife resources are to continue to be a major feature of Yellowstone. The purpose of this report is to briefly summarize and evaluate the published research on winter recreation impacts on wildlife, particularly as they apply to Yellowstone, and to provide recommendations. This may have immediate application in decision-making during the trade-off processes that inevitably must occur when balancing resource conservation with visitor enjoyment.

15. **A partial literature review of the effects of various human activities on wildlife**. Hamilton, N. (1997). Bureau of Land Management. A compilation of selected older studies. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0017-review%20of%20effects%20of%20human%20activities%20on%20wildlife.pdf

16. **Wildlife and recreationists: Coexistence through management and research.** Knight, R. L., & Gutzwiuer, K. J. (1995) Island Press Covelo, CA.

Abstract: Wildlife recreationists define and clarify the issues surrounding the conflict of outdoor recreationists and wildlife. It is a synthesis of what is known concerning wildlife and recreation and addresses both research needs and management options to minimize conflicts.

17. **Impacts of winter recreationist on wildlife in a portion of Yellowstone National Park, Wyoming.** Aune, K. E. (1981) M.S. Thesis, Montana State University, Bozeman.: 111pp.

Abstract: General responses of wildlife to winter recreationists in Yellowstone National Park were attention or alarm, flight, and rarely aggression. Responses varied with the species involved, nature of the disturbance, and time of season. Winter recreation activity was not a major factor influencing wildlife distributions, movements, or population sizes, although minor displacement of wildlife from areas adjacent to trails was observed. Management recommendations are presented.

18. **Impacts of snowmobiles on wildlife.** Bury, R. L. (1978) Transactions of the North American Wildlife and Natural Resources Conference.

Abstract: The major effects of snowmobiles on wildlife appear to be in changes of the animals' daily routine, rather than direct mortality. This seems to be the case with regard to elk, rabbits, and small subnivean animals. Other animals such as deer seem to be more tolerant of snowmobiles. In general, snowmobiles created little effect on large animals, moderate effects were observed on medium-sized animals, and small animals over wintering in sub-snow environments were drastically effected.

19. **Snowmobiles, animals, and man: Interactions and management issues**. McCool, S. F. (1978) Paper presented at the Transactions of the North American Wildlife and Natural Resources Conference.

Abstract: Decisions regarding the opening, closing, or restricting of lands to snowmobile and other off-road vehicle use appears to be more a function of intuitive managerial expertise and judgment and political pressure than a direct result of systematic problem-driven research. Existing research on snowmobile-wildlife impacts has been unable to produce a consensus on the impacts of the activity on a wildlife population. The snowmobile problem results from human behavior and the way humans use snowmobiles. Understanding why humans use snowmobiles, perhaps even to the point of finding effective and acceptable recreational experiences.

20. **Human-wildlife interactions in the Gallatin Range, Yellowstone National Park.** Chester, J. M. (1976) Montana State University, Bozeman.

Abstract: The relationships between the intensity and kinds of human use and the distribution, movements, and behavior of seven species of wildlife in the backcountry areas of the Gallatin Range in Yellowstone National Park were investigated in 1973 and 1974. Except for minor shifts in elk distribution around campsites, variation in the intensity of human use did not appear to be responsible for shifts in wildlife distribution. Wildlife encounters most commonly occurred at distances between 100 and 300 feet, Encounter distances were shortest for mule deer and moose and greatest for bears.

Except for deer and coyotes, which were usually alert or running, all species were most commonly feeding when first observed. In response to knowledge of human presence, the moose was most likely to stand its ground, while bears were the least likely. Wildlife belligerency toward humans was rare. When it did occur, bear and moose were usually involved. Groups of four or more persons experienced lower observation frequencies than smaller groups. Parties of two or less were most likely to encounter grizzly bears. The use of noise did not appear to affect the frequency of wildlife observations or encounters.

21. **Snowmobile tracks and animal mobility.** Hubbe, M. (1973)

Abstract: Impact of snowmobile tracks on animal mobility was studied in Maine in January 1973. The supporting strength of snow and the resistance of snow to impact on/off snowmobile tracks were compared. It was found that the depth an animal sinks in powder snow is proportional to weight and inversely proportional to foot area. Evidence shows an animals ability to walk on crust is inversely related to the kinetic energy of its footfall and proportional to foot diameter. Snowmobile tracks were helpful.

22. **Wildlife-snowmobile interaction project: Preliminary report covering period November.** Huff, D. E. (1972) University of Minnesota and Minnesota Department of Natural Resources Cooperating.

Abstract: There is a strong relationship between numbers of tracks and specific cover types during the winter at Sherburne National Wildlife Refuge; in the most heavily used cover type, oak woods, significantly fewer tracks crossed the snowmobile trail than the snowshoe trail. Major cover types should be considered before constructing snowmobile trails in areas established for wildlife.

23. **Ecological Effects of Snowmobiles.** Neumann, P.W. & Merriam, H.G. – Department of Biology, Carleton University, Ottawa, Canada. (1972) The Canadian Field-Naturalist, Vol. 86, 207-212.

Abstract: Ecological impact of snowmobiles was studied in the Ottawa area. Snow structural changes by snowmobiles had significant effects on temperature gradients, water holding capacity, and melting rate. Snowshoe hare and red fox mobility and distribution also were affected. Snowmobile damage to hardwood saplings and planted pines was significant. Browsing was unaffected except on damaged saplings.

Birds / Eagles

1. **Effects of Winter Recreation on Bald Eagles.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 103-111. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Vehicular activities along prescribed routes or within strict spatial limits and at relatively predictable frequencies are least disturbing to bald eagles (McGarigal et al. 1991, Stangl 1994, GYBEWG 1996). However, slow-moving motor vehicles can disrupt eagle activities more than fast-moving motor vehicles (McGarigal et al. 1991). Snowmobiles may be especially disturbing, probably due to associated random movement, loud noise, and operators who are generally exposed (Walter and Garret 1981). A review of literature revealed that research has not been completed to assess the effects of snowmobile or other winter recreational activities on bald eagle wintering or breeding habitat, but some documents referenced potential effects of snowmobile activities (Shea 1973, Alt 1980, Harmata and Oakleaf 1992, Stangl 1994).

Management Guidelines: Establish buffer zones of 1,300 feet around high-use foraging areas with temporal restrictions from sunset to 10:00 a.m. in areas of high human use. If diurnal perching areas are separate, buffer zones of 650 to 1,300 feet around concentrated or high-use perches should be imposed, dependent on existing vegetative screening. Closures for autumn roosts should extend from 1 October to 1 January, for winter roosts from 15 October to 1 April, for vernal roosts from 1 March to 15 April, or as determined by actual residency patterns of local eagles.

2. **Responses of breeding bald eagles, Haliateetus Leucocephalis, to human activities in North central Michigan.** Grubb, T. G., Bowerman, W.W., Giesy, G.P., & Dawson, G. A. (1992) Canadian Field Naturalist, 106, 443-453.

Abstract: To characterize disturbance and analyze eagle response, we recorded 714 events of potentially disturbing human activity near six pairs of Bald Eagles breeding in north central Michigan in 1990. Vehicles and pedestrians elicited the highest response frequencies, but aircraft and aquatic activities were the most common. Magnitude of response was inversely proportional to median distance-to-disturbance. Seventy-five percent of all alert and flight responses occurred when activity was within 500m and 200m, respectively. Adults responded more frequently than nestlings, and at greater distances to disturbance when perched away from nests. May was the peak month for human activity, most of which occurred on weekends and after noon. Classification tree models are used to assess disturbance-specific response frequencies and to formulate management considerations.

3. **Behavioral responses of wintering bald eagles to human activity on the Skagit River, Washington**. Skagen, S. K. (1980) Paper presented at the Proceedings of the Washington Bald Eagle Symposium.

Abstract: Eagles were found to be more sensitive to disturbance while feeding on gravel bars than while perching, and to approaches by humans on foot and concealed than by people in vehicles. A significant decrease in the proportion of eagles feeding was observed when human activity was present within 200m of the feeding area in the previous 30 minutes. A significant between-season variation occurred in the use of feeding areas relative to human presence, which correlated with food availability. Eagles appeared more tolerant to human activity in the season of low food availability.

4. **Effects of human disturbance on nesting of bald eagles.** Mathisen, E. (1976) The Journal of Wildlife Management, 32(1), l-6.

Abstract: Known nests of bald eagles were divided into three groups reflecting degrees of isolation. The eagle nests under consideration were occupied 182 times from 1963-66. The rate of occupancy was essentially the same for each group. Nesting activity varied from 54% to 48% for the three groups. None of these differences are statistically significant, indicating that human activity is not an important source of disturbance and has no measurable effect on nesting success or nest occupancy.

Birds / Pheasants

1. **Effects of snowmobile activity on wintering pheasants and wetland vegetation in Northern Iowa marshes.** Sodja, R. J. (1978) M.S. Thesis. Iowa State University, Ames, IA: 67pp.

Abstract: Effects of dispersed snowmobile use on ring-necked pheasants and marsh vegetation were studied in Iowa. No effects of snowmobiling on pheasant movements or behavior were found. Observed vegetation changes did not appear to seriously alter wildlife.

Birds / Trumpeter Swans

1. **Effects of Winter Recreation on Trumpeter Swans.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 113-116. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Aune (1981) found that swans appeared to become habituated to moving snowmobiles, but that they fly or swim away upon approach by foot or ski or when a snowmobiler stopped. Aune noted that, in general, animals function best in a predictable environment. Groomed routes, both for snowmobilers and skiers, create a more predictable environment.

Management Guidelines: Designating snowmobile and ski trails away from open waters used as winter habitat by swans can mitigate winter recreational impacts on the birds. Special restrictions may need to be implemented on open-water snowmobiling in areas that swans routinely use for feeding. Some concern has been raised about the effects of snowmobile noise on swans; however, at this time no information is available on this subject.

Bear / Black

1. **Winter recreation and hibernating black bears-Ursus Americanus.** Goodrich, J. M., & Berger, J. (1994). Biological Conservation, 67: 107-110.

Abstract: Denning ecology of hibernating black bears was studied for 3 winters in the Sierra Nevada and Sweetwater Mountains in Nevada and California. Researchers did not document den abandonment due to recreational disturbance; bears at both sites abandoned dens and cubs in response to researchers approaching den sites, and all but one bear remained active after abandonment. The researchers concluded that the high overlap between bear den sites and potential winter recreation areas indicated a high potential for den abandonment due to human disturbance.

Bear / Grizzly

1. **Effects of Winter Recreation on Grizzly Bears.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 37-47. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Snowmobile traffic alone on highly and moderately groomed routes does not present a significant impact to bears during most of the winter months. This is because of the predictability of defined snowmobile corridors and because most snowmobile use occurs during the time that bears are in hibernation. Conflict could occur when snowmobile use coincides with spring bear emergence and foraging. Most use of ungroomed snowmobile areas should not conflict with bear activity because it coincides with bear hibernation. Moreover, areas of ungroomed snowmobile use typically occur at elevations above spring bear habitats. An exception is when over-wintered whitebark pine crops are available, and bear forage at high elevations in the spring. Another possible effect may occur because most backcountry snowmobile use occurs at higher elevations, where most bear denning is found. The potential for conflicts between bears and recreational users does exist when dispersed use occurs after bear emergence (between March 1 and March 15).

Management Guidelines: Grooming and use of snowmobile roads and trails should end by March 15 in areas where post-denning bear activity is high. Where winter use occurs in ungulate wintering areas, activity should end by March 15. In areas with whitebark pine forests, a primary issue is the displacement of bears. Because the presence of over-wintered pine nut crops is not consistent, this is an episodic and not an annual concern. Therefore travel restrictions should be addressed based on yearly monitoring rather than as a continuous restriction.

Caribou / Mountain

1. **Periodic status review for the woodland caribou in Washington.** Wiles, G. J. (2017) Washington Department of Fish and Wildlife, Olympia, Washington. https://www.snowmobileinfo.org/snowmobile-access-docs/Periodic-Status-Review-for-the-Woodland-Caribou-in-Washington.pdf

Executive Summary: Woodland caribou (Rangifer tarandus caribou), a subspecies of caribou, occur across the boreal regions of North America and are comprised of eight recognized populations. The southern mountain caribou population consists of 17 subpopulations, or herds, with the South Selkirk subpopulation being one of these. This subpopulation occurs in the southern Selkirk Mountains of southeastern British Columbia, northeastern Washington (in Pend Oreille County), and northern Idaho, and is the only caribou herd that ranges into the contiguous U.S.

Southern mountain caribou are distinguishable from other populations of woodland caribou by their inhabitation of mountainous areas with deep snow accumulations and their winter diet of primarily arboreal lichens. These caribou prefer large areas of late successional conifer forests throughout the year and migrate seasonally to different elevations and forest types to seek food and suitable calving sites.

Overall abundance of southern mountain caribou has declined 45% since the late 1980s and was estimated at 1,544 animals during 2008-2014. Eleven of the 17 subpopulations show declining trends, nine hold fewer than 50 animals, and two have been extirpated since 2003. The South Selkirk subpopulation was considered abundant and possibly numbered in the hundreds in the late 1800s, but decreased to an estimated 25-100 caribou between 1925 and the mid-1980s. Numbers ranged between 33 and 51 animals from 1991 to 2009 despite being supplemented with 103 caribou in two separate multi-year translocations in the late 1980s and 1990s. Most recently, the subpopulation declined rapidly from 46 to 12 caribou between 2009 and 2016. The percent of calves in the subpopulation during late winter surveys averaged 9.9% per year from 2004 to 2016, which is below the estimated 12-15% needed to maintain a stable population with high adult survival. Additionally, the South Selkirk subpopulation is isolated from neighboring subpopulations, with probably no immigration occurring in recent decades.

Predation is considered the most immediate threat to the South Selkirk subpopulation. Although robust caribou populations are able to withstand some level of natural predation, any amount of predation on the now very small South Selkirk subpopulation is likely to greatly affect its future sustainability. In addition, past conversion of old-growth forests to earlier successional stages have brought higher densities of deer, moose, and elk and their predators (i.e., wolves, cougars, and bears) into closer proximity to herd members, resulting in greater predation risk to caribou. Other threats to the subpopulation are highway collisions, human disturbance associated mostly with winter backcountry recreation, small population size coupled with isolation, and climate change.

The small size and ongoing decline of the South Selkirk subpopulation has increased its risk of extirpation. It is therefore recommended that woodland caribou remain a state endangered species in Washington.

2. **Selkirk Ecosystem Woodland Caribou Movement Analysis.** Wayne Wakkinen, Sr. and J. Brent Slone (2010) Idaho Dept. of Fish and Game. https://www.snowmobileinfo.org/snowmobile-access-docs/Selkirk-Ecosystem-Woodland-Caribou-Movement-Analysis.pdf

Executive Summary: This investigation used over 4,000 aerial telemetry locations of 66 individual woodland caribou obtained from 1988-2006 to investigate seasonal home range characteristics, inter-seasonal movements, seasonal site fidelity, and to model potential movement corridors within the Selkirk Ecosystem. Each year was divided into 4 seasons based on elevational changes by caribou: Spring (Apr 20 –Jul 7), Summer (Jul 8 –Oct 16), Early Winter (Oct 17 –Jan 18), and Late Winter (Jan 19 –Apr 19).

Woodland caribou in the Selkirks had smaller home ranges, smaller daily movements, and more linear as opposed to round home ranges during winter seasons than other seasons. The smaller home ranges and smaller movements during winter are consistent with an energy conservation strategy. Caribou are likely to be the most affected by disturbance and displacement during the late winter period. Late winter should receive management priority when considering human activities with the potential for displacement. However, habitat quality, occupation by caribou, and the potential for recolonization must also be considered when evaluating management actions.

We calculated the distance between arithmetic centers of successive seasonal home ranges for individual caribou. We also investigated long distance moves (>10 km) between successive seasonal home ranges. There was no statistical difference detected among inter-seasonal movement distances. Median movement distances between seasons varied from 6.1km (late winter to spring) to 7.8km (summer to early winter). There was also no statistical difference detected among long-distance (>10 km) inter-seasonal movements. Median long-distance movements varied from 12.7km (summer –early winter) to 14.8km (early winter to late winter and late winter to spring). There is no indication that longer distance moves took place during any specific inter-seasonal period. All inter-seasonal periods have an equal likelihood to support moves that allow genetic flow within the ecosystem or to recolonize unoccupied habitat.

Site fidelity is a measure of an animal to return to an area that it previously occupied. We examined the tendency of caribou to return to areas that were used in previous years during the same season (e.g., late winter 1997 –late winter 1998). Seasonal site fidelity varied from 50% in late winter to 78% in early winter. Variable snow pack can influence lichen availability in the winter, possibly explaining the lower site fidelity during late winter. Therefore, management actions should seek to maintain forage area options for caribou during this season.

We modeled potential travel corridors for woodland caribou within the Selkirk Ecosystem based on landscape resistance, using Corridor Designer software (Northern Ariz. Univ.). We assumed that habitat quality relates directly to permeability, or the ease at which an animal can move through the landscape. As part of the modeling process, we used a moving window analysis (4.4 km radius) to identify high-quality habitat blocks with a minimum patch size of 61.8 km2, the average size of a seasonal home range. We developed a selection screen to identify important habitat blocks that serve as corridor terminal points. Using these terminal points, the modeling software identified 12 potential movement corridors within the ecosystem. Corridor Designer generates multiple corridors between the terminal points that vary in width by utilizing incremental percentages of the landscape. We evaluated the 12 corridors that had a minimum width of 2 km throughout at least 90% of its length. Two kilometers is approximately 3 times the average daily movement. Each corridor was evaluated based on a generalized habitat quality map and on seasonal maps (Spring, Summer, Early Winter, Late Winter). These modeled movement corridors have the potential to aid in the recolonization of habitat which is suitable but currently unoccupied and to facilitate genetic interchange throughout the ecosystem.

3. **Snowmobiling and Mountain Caribou: A Literature Review of Stewardship Practices.** Mitchell, Selina and Hamilton, D. (2007) Nanuq Consulting Ltd., Nelson, BC http://www.socio-ecologicalsolutions.com/storage/SPOR_Snowmobile_Caribou_V4Final_Dec2007.pdf

Objective: The objective of this project was to compile a compendium of stewardship practices for the Caribou/Snowmobiling Activity-Habitat Pair as outlined in the "Information for Outdoor Recreation and Tourism Proposed Signatory Document" (Fletcher and Geisler 2006). This document is intended to support the Stewardship Practices for Outdoor Recreation partnership initiative to improve dissemination of information pertaining to backcountry recreation stewardship throughout recreational organizations and small businesses in British Columbia.

Suggested Stewardship Practices for Snowmobiling in Caribou Habitat
Two basic premises accompany the stewardship practices presented in this document:
1) snowmobiling activity in caribou habitat is assumed, excluding those areas where closures are already established; and
2) it is the responsibility of the individual (or group) to be informed and become knowledgeable in the practices required to operate a snowmobile(s) in caribou habitat.

SNOWMOBILER RESPSONSIBILITIES

1. *Become well-informed about the area you plan to snowmobile in.* Any individual who is snowmobiling in BC should contact the local snowmobile club in the area of planned activities to determine where wintering mountain caribou may reside and become familiar with all restrictions and regulations pertaining to mountain caribou conservation in these areas. Local club representatives are knowledgeable about the regulations and the management plans that have

been implemented to protect caribou in their area. Some examples of this basic knowledge include

- caribou ecology (winter seasonal use patterns and distribution);
- local or population level caribou/snowmobile access plans and snowmobiling restrictions;
- basic stewardship practices required to mitigate conflicts between caribou and snowmobiles; and,
- implications and potential conflicts created when snowmobiling in caribou habitat (i.e., how the actions of the few reflect on the many).

Under snowmobile management agreements, both provincial and local snowmobile clubs have assumed various levels of responsibility to educate both their members and non-affiliated snowmobilers about snowmobiling in areas occupied by caribou. Potential contact sources are listed in the table below. A recently issued government brochure entitled "Snowmobiling and Caribou in British Columbia" and the document "Snowmobiling in the Columbia and Rocky Mountains of British Columbia" has been widely distributed throughout BC and outline proper etiquette when snowmobiling in caribou habitat.

2. *Be vigilant for posted regulations and restrictions*. Be aware of closures and regulations within your snowmobiling area. Not only are there potential adverse implications to the endangered mountain caribou, there are also personal legal ramifications and penalties and implications to the snowmobile community-at-large for the actions of individuals. The misguided adventures of one or more individuals can reflect and have negative consequences on the majority of responsible snowmobilers and the snowmobiling community. To access information on snowmobile closures areas, consult the BC Hunting and Trapping Synopsis, available at local government offices and on the web: http://www.env.gov.bc.ca/fw/wildlife/hunting/regulations/

3. *While snowmobiling follow best stewardship practices to reduce your impact on caribou:*
   - If caribou tracks are observed do not follow the tracks.
   - If you see caribou, do not approach.
     - Approaching caribou, either by snowmobile or foot, may disturb caribou or cause them to retreat into areas of lesser quality habitat, where greater energy may need to be expended to meet daily requirements for survival.
   - Make every effort to minimize disturbance.
     - If caribou are close, turn off your snowmobile and allow the animals to calmly move away.
     - The effects of snowmobiles on caribou are reduced by maintaining a sufficient distance from the animals. Caribou may cease to withdraw if a snowmobile approach is halted. A separation of at least 500 m from caribou is recommended.
   - Take precautions to stay away from caribou when encountered.
     - If by random chance you encounter caribou, leave the area. After encountering mountain caribou and taking the precautionary steps to reduce their response to your presence (see above), it is recommended that snowmobilers leave the area. Apparently, "strong and lasting" effects on caribou may not be noted when snowmobiles are no longer present within high-use snowmobile areas (Powell 2004).
     - Do not make caribou run from your snowmobile. Horejski (1981) suggests that snowmobile speed is a factor in caribou disturbance (limiting speed may limit the "looming" effect that caribou supposedly experience in the presence of an approaching snowmobile). It is suggested that one of the best ways to minimize disturbance is to prevent the caribou from running in response to the snowmobile (Powell 2004). Along

with energy expenditures, the amount of time that it takes caribou to recover from disturbance and return to predisturbance activities increases when caribou run.

4. *Diminish your impact on caribou by adjusting/refitting your snowmobile*. Noise may be a factor in caribou disturbance. Although noise may not be the primary cause of disturbance (human scent appears to have a much greater effect on caribou), various technologies exist that can minimize snowmobile noise. Therefore, this type of disturbance can be mitigated. Try and diminish the amount of noise that your snowmobile produces:
   - Use 4-stroke engines
   - Use mufflers designed to decrease the amount of noise produced by your machine
   - Ensure that equipment is properly maintained

5. *Report any infractions of snowmobile regulations*. Observe Record and Report: One of the easiest ways to do this is through the Report All Poachers and Polluters (RAPP) program. This BC Government program offers a 24 hour hotline for contacting Conservation Officers. Phone: 1-877-952-7277. Cellular Dial #7277.

   PROACTIVE GUIDANCE BY SNOWMOBILE CLUBS

6. *Teach snowmobilers about caribou and best stewardship practices for your areas*. Under numerous snowmobile management agreements, snowmobile clubs have the responsibility to educate both their members and non-affiliated snowmobilers regarding caribou.

7. *Gather information on caribou in your region and participate in caribou management planning*.
   - Contact the Species at Risk Coordination Office (SARCO)
   - Contact caribou experts and regional/local government officials
   - Invite caribou experts to engage in club meetings and activities
   - Participate in strategic planning activities around managing snowmobile areas
   - Critique and develop caribou management plans within collaborative meetings involving various stakeholders

8. *Disseminate information to as many snowmobilers as possible*. Some preliminary studies suggest that individuals riding in managed snowmobile areas within BC may not understand the rules and regulations governing these riding areas. In some regions of BC, the majority of snowmobilers are out-of-province riders. BC clubs must educate these riders if management areas are to be successful.
   - Network with out-of-province clubs
   - Place information signs regarding snowmobile zones at the beginning of access roads and throughout snowmobile areas
   - Place brochures regarding mountain caribou with snowmobile clubs and at various locations throughout communities, including tourist information centres, snowmobile shops, restaurants, and accommodations
   - Increase public media announcements regarding caribou habitat and snowmobile best practices

4. **A Strategy for the Recovery of Mountain Caribou in British Columbia.** The Mountain Caribou Technical Advisory Committee (2002) British Columbia Ministry of Water, Land and Air Protection http://www.env.gov.bc.ca/wld/documents/mtcaribou_rcvrystrat02.pdf

Executive Summary: The Strategy for Recovery of Mountain Caribou is a document for planning recovery actions for the Mountain Caribou, an arboreal lichen–winter feeding ecotype of the Woodland

Caribou (*Rangifer tarandus caribou*) found primarily in southeastern British Columbia. It is intended to support a National Recovery Strategy for Woodland Caribou. The national strategy will include, but is not limited to, Mountain Caribou. The national strategy is the first part of a two-part National Recovery Plan for Woodland Caribou; the local population-specific Recovery Action Plans is the second part.

Section I provides the introduction and background information. The British Columbia Conservation Data Centre (CDC) placed the Mountain Caribou on the provincial Red List in 2000. The CDC Red List includes species that are candidates for legal status as provincially Threatened or Endangered. The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) designated caribou in the Southern Mountains National Ecological Area (SMNEA), including all Mountain Caribou, on their Threatened list in May 2000 and reaffirmed this designation in May 2002. The COSEWIC designation includes species that are candidates for formal national Threatened status under the new federal *Species at Risk Act* (SARA). A small, trans-boundary population of Mountain Caribou in the South Selkirks was officially designated as Endangered in the United States in 1984. Thus, BC has provincial, national and international responsibilities for maintaining Mountain Caribou.

Section II, Evaluation of Conservation Status, first identifies factors contributing to vulnerability and Threatened status, then examines the role of Mountain Caribou in the ecosystem and interactions with humans. Historically, Mountain Caribou were apparently more widely distributed and abundant than today. One estimate is that Mountain Caribou have been extirpated from 43% of their historic BC range. British Columbia currently has an estimated 1900 Mountain Caribou distributed in 13 local populations that collectively form a metapopulation. Widespread habitat alteration, past over-hunting and increased predation are believed to have contributed to the disappearance of Mountain Caribou from portions of their historic range in BC. Today, the primary threat to Mountain Caribou appears to be fragmentation of their habitat. Associated with this fragmentation are potential reductions in available winter food supply, increased human access and associated disturbance, and alteration of predator-prey relationships. For these reasons, forest practices are currently considered to be the greatest habitat management concern. Increasing interest in mechanized backcountry recreation poses a more recent potential threat to caribou.

General considerations for recovery under Section II outlines a conservation ranking for local populations and presents a conservation approach that employs the metapopulation concept, the precautionary principle, adaptive management and ecosystem management principles. The most effective means to satisfactorily resolve conflicts between management of habitat for Mountain Caribou and competing land uses is to use existing information and conservation principles over the short term, employ adaptive management over the longer term and ensure full participation of all relevant stakeholders in the decision-making process.

Recovery Goals and Objectives under Section III identifies three goals and associated objectives to advance the recovery of Mountain Caribou: Recovery goals include: (1) a metapopulation of 2500-3000 caribou distributed throughout their current range in BC; (2) enhancement of identified local populations; and (3) public support for the recovery of Mountain Caribou and their habitats. Goal 3 recognizes that integrated resource management and public interest and involvement are key to recovery.

In Section III, Provincial Approaches for Recovery, 20 recovery approaches and associated recovery actions are identified. For each approach, the status, the recovery actions proposed and some possible concerns with implementing the actions are identified.

Section IV, Recovery Strategy Implementation, identifies three general principles for realizing the recovery goals and objectives. These include ensuring that recovery actions will be science-based, that recovery will be based on shared stewardship and that recovery will be based on financial capacity. It is recognized that maintaining Mountain Caribou and their habitat in perpetuity throughout their range will require the cooperation of government agencies, the forest industry, commercial recreation operators, local communities, First Nations and non-government organizations (NGOs). An implementation schedule (Table 12) is provided which identifies the priority for recovery approaches, possible co-operators, target date for completion and required funding. The schedule should be used in the regular monitoring of all provincial recovery actions and as a basis for the funding of recovery measures. The schedule should also be reviewed on an annual basis to evaluate progress and to update activities according to changing circumstances.

A major purpose of the Strategy for Recovery of Mountain Caribou is to outline a strategy that will lead to down-listing of Woodland Caribou from their Threatened status under COSEWIC for the SMNEA. Implementing the provincial approaches for recovery will require an estimated $3.5 million over five years. The recovery strategy should be updated as new information becomes available, and revised every five years until down-listing has been achieved.

5. **Impacts of Backcountry Recreation Activities on Mountain Caribou: Management Concerns, Interim Management Guidelines and Research Needs.** Simpson, K. and Terry, E. (2000) British Columbia Ministry of Environment, Lands and Parks – Wildlife Branch, Victoria, BC http://www.env.gov.bc.ca/wld/documents/techpub/wr99.pdf

Abstract: Mountain caribou are currently red-listed in British Columbia, and have been the focus of forestry-related conflicts for many years. Due to an increase in winter backcountry activities, however, there are growing concerns about the impact of these activities on caribou winter habitat use. This report addresses the potential impacts of four winter backcountry recreation activities on Mountain Caribou, including snowmobiling; heli-skiing; snow-cat skiing and backcountry skiing. Relative to other winter backcountry recreation activities, snowmobiling has the greatest perceived threat to mountain caribou. Management concerns for each Mountain Caribou subpopulation are reviewed, and the probable degree of threat associated with each recreational activity is identified. Interim management guidelines that are either currently in place, or could be considered as options to reduce potential impacts, are outlined. A research approach is suggested to objectively assess risks and answer key questions regarding backcountry recreation impact on caribou.

Potential Impacts of Backcountry Recreation Activities on Mountain Caribou – Snowmobiling: Although the effects of snowmobiling on various North American ungulate species have been reported (Dorrance et al. 1975; Richens and Lavigne 1978; McLaren and Green 1985; Freddy et al. 1986), overall, the scientific literature available on the impacts of snowmobile activity and human disturbance on Caribou remains somewhat limited. The published research on Caribou has primarily focused on Barren Ground Caribou (*Rangifer tarandus granti*) and Reindeer (*Rangifer tarandus platyrhyncus*) that live in open arctic environments (Smith 1988; Tyler 1991). The effects of human disturbance (noise, blasting) on Woodland Caribou (*Rangifer tarandus caribou*) has also been reported (Bradshaw et al. 1997), however, only one study has specifically addressed the impacts of snowmobile activity on the Mountain Caribou ecotype (Simpson 1987).

Overall, these studies suggest the relative impacts of snowmobile activity on ungulates vary with each species, the frequency of snowmobile traffic, noise levels, rate of travel (i.e., snowmobile speed), human scent, visibility and terrain type (open vs. forested).

Relative to other winter backcountry recreation activities, snowmobiling has the greatest perceived threat to Mountain Caribou primarily because high capability snowmobile terrain tends to overlap with high capability Caribou winter range, and snowmobiles can easily access and potentially affect extensive areas of subalpine winter range (Simpson 1987; Webster 1997). Subalpine and alpine ridges not only provide ideal terrain and viewscapes for snowmobilers, but also provide preferred late winter range (Jan–Apr) for all Mountain Caribou sub-populations in British Columbia (Simpson et al. 1997). Therefore, the primary concern is related to habitat displacement from preferred late winter foraging areas, which can result in a decline in physical body condition due to reduced forage intake and increased energy expenditure. Habitat displacement could also result in increased mortality risks by forcing Caribou into steeper terrain that is more susceptible to avalanches. Another concern related to snowmobile activity is the hard-packed trails they provide for predators (e.g., wolves and Cougars). Hard-packed trails allow easy access for predators to reach subalpine foraging areas, which are typically not available to them because of the deeper snow conditions at these elevations compared to lower elevation valley bottom habitats (Bergerud 1996). Although predation (primarily summer) has been shown to limit some Caribou populations (Seip 1992), it is unclear to what extent winter predation contributes to Caribou mortality and population dynamics.

Although the primary concern is related to disturbance of late winter ranges (i.e., alpine/subalpine snowmobiling), Caribou may also be disturbed while on their early winter ranges which include mid- and lower elevation forests (i.e., mid elevation ESSF and ICH habitat types). Snowmobiling in these forested areas may occur as part of commercial trail-based operations (groomed trails) or when high country snowmobilers access alpine areas.

The relative magnitude of potential impacts from snowmobiling is partly related to accessibility. Snowmobile areas that are occupied by Caribou and can be easily accessed from major highways and/or logging/mine roads are most vulnerable to disturbance due to potentially greater use. Therefore, because road access is expected to continue to increase over time (logging/mining), the potential for snowmobiles to reach remote areas will also increase. In addition, there is growing demand for fresh powder snowmobiling, which has resulted in some transportation of snowmobiles by helicopter to alpine areas. This activity could have potential cumulative effects from both helicopter and snowmobile disturbance as well as from the hard-packed trails.

<u>Interim Management Guidelines:</u> To address the potential negative effects of backcountry recreation activities on mountain Caribou, the following section briefly outlines interim management guidelines that are either in place or could be considered as options to reduce potential impacts. Because there is a clear need to conduct research studies that examine how Caribou are affected by backcountry recreation activities and to evaluate the effectiveness of management guidelines, these measures should be viewed as 'working hypotheses'. Moreover, because there is inherent uncertainty regarding the specific responses of individual Caribou and even more uncertainty regarding population or demographic consequences these interim measures reflect the *precautionary principle*. Some of these management guidelines have been taken from the Draft Recreation and Wildlife Policy report currently being prepared by the Wildlife Branch.

In areas where there is both high capability snowmobile terrain and/or heli-skiing as well as high capability Caribou winter range, the following recommendations are suggested:

- Preclude snowmobile use within high sensitivity areas. These areas typically include late-winter subalpine parkland foraging areas but may also include mid- and low-elevation early-winter habitats.
- Regulate snowmobile activity through zoning and timing restrictions in areas with existing snowmobile use that are occupied by Caribou.
- Prohibit trail expansion into new areas occupied by Caribou.
- Focus trail expansion and encourage use in areas that already receive extensive snowmobile use and where Caribou are rarely present (e.g., Yanks Peak, George Mountain, Boulder Ridge).
- Consider designating new trails in areas which snowmobilers wish to access but are used less by Caribou (e.g., glaciers). Ideally these would occur in areas that do not conflict with heli- or backcountry ski touring.

- Promote responsible snowmobile club policies such as off-trail restrictions, code of conduct and self-policing, similar to management guidelines developed for the Revelstoke area.
- Limit helicopter flight altitudes to above 300 m in areas of high capability Caribou habitats.
- Avoid known high suitability winter range areas with designated (approved) flight paths.
- Examine the feasibility and cost-effectiveness of using Conservation Officers/Park Wardens to conduct periodic monitoring of high use snowmobile areas.
- Develop an education program (extension materials) designed to inform the public about Caribou and risks of disturbance.

6. **Selkirk Mountains Woodland Caribou Herd Augmentation in Washington: A Cooperative Interagency Plan.** Audet, S. and Allen, H. (1996) Washington Department of Fish and Wildlife; U.S. Fish and Wildlife Service; U.S. Forest Service; British Columbia Ministry of Environment, Lands and Parks, and Idaho Department of Fish and Game
   http://wdfw.wa.gov/publications/00448/wdfw00448.pdf

Executive Summary: The Selkirk Mountain woodland caribou (*Rangifer tarandus caribou*) is listed by the U.S. Fish and Wildlife Service as an endangered species in the United States. It is also designated as an endangered species in Washington by the Washington Department of Fish and Wildlife. The recovery plan for the caribou (USFWS, original 1985; revised 1994) includes a task to establish caribou in the western portion of the Selkirk Ecosystem in Washington. Transplants to the western portion of the ecosystem are needed to achieve better distribution, greater abundance, and to enhance the probability of caribou recovery.

The augmentation project entails capturing caribou in separate, but genetically similar subpopulations in British Columbia, transporting the animals to Washington, releasing them into the wild, and monitoring the results. Previous herd augmentation efforts for the southern Selkirk caribou population involved transplanting caribou from healthy populations in British Columbia to the Ball Creek area of Idaho. A total of 60 caribou were transplanted: 24 in 1987; 24 in 1988; and 12 in 1990. Information and experience gained in the Idaho effort will be used to increase the chances for success of the Washington project.

Three potential sources for transplant animals in British Columbia will be considered: Revelstoke, Blue River/Wells Gray Park, and Prince George. British Columbia officials will determine the number and sources of transplant animals. The target number of animals for the first year will be 20-24 animals, with a sex ratio of 1 male: 4-5 females. Preferred age composition is males 3 years or younger, calves, yearlings, and adult females. Old-aged females or animals in poor condition will be excluded. Methods will follow those used in the Idaho augmentation effort, which experienced very low mortality rates. Animals will be captured in March, using net guns from helicopters. They will be held for tuberculosis and brucellosis testing and then transported to the release site in Washington.

Four potential release sites on the Sullivan Lake Ranger District of the Colville National Forest were evaluated. One site, Molybdenite Ridge was eliminated from consideration. Potential release sites, in order of preference are: Pass Creek, Mankato Mountain, and upper Sullivan Creek. All are within the Caribou Habitat Area, are currently managed as caribou habitat under the Colville National Forest Plan (U.S. Forest Service 1988), and will require no change in management to accommodate the augmentation effort. The final site selection will depend upon weather conditions and road access at the time of release.

Preliminary work (administrative, habitat mapping, caribou feeding trials) has been conducted during 1995 to facilitate the augmentation project. Pending funding approval, the first transplant will take place in March 1996. Caribou recovery is an interagency and international effort requiring public support and involvement. Law enforcement needs are identified in the augmentation plan and will emphasize

prevention of accidental or intentional shooting. Information/Education needs are also addressed in the plan. Some of the information/ education efforts used during the Idaho augmentation effort, such as the "Adopt a Caribou" program, will be used in the Washington project.

Carnivores / Mid-Size

1. **Effects of Winter Recreation on Mid-Sized Carnivores (Wolverine, Fisher, Marten, Lynx, Bobcat, Red Fox, and Weasel).** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 65-71. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Mortality resulting from an accidental collision with a snowmobile is possible, but the probability is low. Intentional killing of carnivores by a snowmobiler is possible, but most likely it would occur in rare, isolated incidents.

Management Guidelines: A literature search produced little information on how winter recreational activities impact carnivores; research on carnivores is extremely expensive and is mostly non-existent on mid-sized carnivores.

Coyotes

1. **Effects of Winter Recreation on Coyotes and Lynx.** J. R. Squires, L. F. Ruggiero, J. A. Kolbe, and N. J. DeCesare (2006) USDA Forest Service, Rocky Mountain Research Station, Missoula, Montana https://www.snowmobileinfo.org/snowmobile-access-docs/Effects-of-Winter-Recreation-on-Coyotes-and-Lynx.pdf

Summary of Findings: Coyotes remained in lynx home ranges throughout the winter and the distance they traveled from compacted snowmobile trails did not vary as snow conditions changed or as winter progressed. Although coyotes used compacted snow significantly more than random expectation, they did not travel closer to snowmobile trails than randomly expected. Coyotes traveled on snowmobile trails 7.7 % of the time and for short distances (median = 124 m, Table 5). Interestingly, coyotes traveled along uncompacted forest roads 4.6 % of the time which was statistically similar to the distance that they traveled along forest roads compacted by snowmobiles (5.7 % of travel). This suggests that coyotes may select for the roads' structure (a cleared travel corridor) and location rather than the compacted snow sometimes present on them. In addition, coyotes strongly selected for naturally shallower and more supportive snow surfaces when traveling off compacted snowmobile trails. Coyotes were primarily scavengers in winter (snowshoe hare kills comprised only 3% of coyote feed sites, Table 6) and did not forage closer to compacted snowmobile trails than random expectation.

Our results suggest that the overall influence of snowmobile trails on coyote movements and foraging success was minimal on our study area. It is unlikely that compacted snowmobile trails increased competitive interactions between coyotes and lynx during winter.

Deer

1. **Ungulates effects of recreation on Rocky mountain wildlife: A review for Montana.** Canfield, J. E., Lyon, L.J., Michael, H.J. & Thompson, M.J. (1999) Montana Chapter of the Wildlife Society.

Abstract: Ungulates provide a large percentage of the recreational opportunities for wildlife enthusiasts in the State of Montana. Hunting, wildlife viewing, and photography generate economic benefits in excess of $450 million annually. However, recreational activities have the potential not only to displace ungulates to private land where they may cause damage, but also to have negative direct and indirect effects to the populations themselves. During winter, many ungulates are seasonally confined to restricted geographic areas with limited forage resources. In these conditions, physiological adaptations and behavioral adaptations tend to reduce energy requirements. Despite lowered metabolic and activity rates, most wintering ungulates normally lose weight. Responses of ungulates to human recreation during this critical period range from apparent disinterest to flight, but every response has a cost in energy consumption. Snowmobiles have received the most attention compared to other wintertime disturbances, and the majority of reports dwell on negative aspects of snowmobile traffic.

However, snowmobiles appear less distressing than cross-country skiers, and for several ungulate species, the greatest negative responses were measured for unpredictable or erratic occurrences. In addition to increasing energy costs for wintering animals, recreational activity can result in displacement to less desirable habitats, or in some situations, to tolerance of urban developments. Tendencies to habituation vary by species, but habituated ungulates are almost always undesirable.

Managers can provide an important contribution to energy conservation by reducing or eliminating disturbance of wintering ungulates and restricting recreational use of spring ranges that are important for assuring recovery from winter weight loss. During summer, the biological focus for ungulates includes restoring the winter-depleted body condition and accumulating new fat reserves. In addition, females must support young of the year and males meet the energy demands of horn and antler growth. The potential for impacts increase and options for acquiring high quality nutrition, with the least possible effort, decline as the size of the area affected by recreationists expands to fill an increasing proportion of summer range. Disturbance of the highly productive seeps and wet sites may cause animals to withdraw to less productive areas. In addition, ungulates may be especially vulnerable to disturbance around special habitat features, such as salt licks. Persistently high levels of recreational use and the proximity to human population centers is predicted to impact reproductive performance of ungulate populations, but little direct research at this level of disturbance has been reported. Recreational traffic on and off roads has been linked with high rates of establishment and spread of noxious weeds in wildlife habitat.

The importance of summer range to most ungulate populations has gone unrecognized for many years. It is apparent, however, that managers can contribute substantially to the health, productivity, and survival of these populations by reducing human disturbances to summering animals. Big game hunting has more immediate effects on ungulate population densities and structures than any other recreational activity. Hunting season security and management affects short and long term hunting opportunities. Managers of public lands control only a few of the potential variables that contribute to security; including retention of important vegetative cover, travel management, and enforcement of travel regulations. There is a strong relationship between adequate security and predicted buck/bull carryover, but excessive hunter numbers will overwhelm any level of security. Hunting also has the potential to negatively affect herd productivity as mature males are lost from populations. Violations of ethical considerations including the concept of "fair chase" and the perception of the "sportsman" in the public mind, can increase ungulate vulnerability as well as influence social acceptance of the sport of hunting. Pursuit of pronghorns with ORVs and killing of trophy animals within game farm enclosures are presented as ethical violations.

2. **How off-highway vehicles affect deer.** Laing, M. E. (1992) National Off-Highway Vehicle Conservation Council: 1-4 http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0015-how%20OHV%20affect%20deer.pdf

Abstract: A NOHVCC Fact Sheet summarizing seven studies by different researchers in seven different sites. Habituation to predictable motor vehicle activity was a consistent finding.

3. **Rock Creek off-road vehicle/deer study.** Jones & Stokes Associates, Inc. (1991) Prepared for CA. Department of Fish and Game; CA. Department of Parks and Recreation and El Dorado National Forest, Sacramento, CA. *(NOTE: included as an example of how newer ORV study results are comparable to old snowmobile studies)*

Abstract: The response of six to eight radio-collared deer to four levels of ORV use was determined by evaluating changes in the size of 2-day activity centers and foraging behavior. During low levels of use approximately 13 riders per day were in the study area; approximately 28 riders per day were present during moderate levels; and 47 riders per day were present during high levels of ORV use. No ORV use was used as a control.

No statistically significant differences were detected in the size of 2-day activity centers or the amount of feeding time along the different levels of ORV use. This study concluded that the deer at Rock Creek were not affected by the ORV's because no trends in the data existed to suggest otherwise. The total amount of time that deer foraged and the daily cycle of feeding periods were similar to populations of deer that had not been disturbed by ORV's. There was a low probability of an ORV encountering a deer because of the low population densities and large home ranges in the study area. Hikers had a minimum amount of disturbance on deer mostly related to harassment by dogs. This was decreased with education of visitors. Further impacts can be reduced by moving ORV use out of deer critical habitat.

4. **Rock Creek Off-Road Vehicle/Deer study – Interim Report.** Jones & Stokes Associates, Inc. (1990) California Department of Fish and Game and California Department of Parks and Recreation and El Dorado National Forest. . *(NOTE: included as an example of how newer ORV study results are comparable to old snowmobile studies)*

Abstract: The study was conducted to determine the response of mule deer to off-road vehicle use and other forms of recreation. The interim report describes the work completed in 1990. The flight response of deer at Rock Creek suggests they were not as wary of people as other deer herds, and this may result from the difference in habitat types between study areas. Distribution of deer was not affected by hikers and equestrian/mountain bike riders. Different recreation levels had no effect on deer.

5. **Responses of black-tailed deer to off-highway vehicles in Hollister Hills State Vehicular Recreation Area Hollister, CA.** Ferns, R. M., & Kutiiek, M.J. (1989) Department of Biological Sciences, San Jose State University: 42pp. . *(NOTE: included as an example of how newer ORV study results are comparable to old snowmobile studies)* http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0035-black%20tailed%20deer%20in%20hollister%20hills.pdf

Abstract: The responses of black-tailed deer were studied at Hollister Hills State Vehicular Recreation area in Hollister, CA. Researchers captured 14 female deer and equipped them with radio-collars. Movements, habitat use, and activity levels were recorded for one year and compared with OHV levels. Home range sizes for deer living within the riding area were similar to those of previously studied deer populations living in similar habitats but were not exposed to OHV use. No significant correlation was found between OHV activity levels and deer activity levels. Deer generally avoided OHV riding areas during peak use but returned to their established home ranges after traffic levels subsided. Studies have shown that animals reacted minimally to disturbances on established trails and roads but there were increased responses to disturbances where none had occurred before. Researchers found that home-ranges of deer at Hollister Hills were centered around water and food supplies. It is recommended that future trails are developed away from major drainages and other preferred habitat types. An effort should also be made to educate trail users and encourage them to ride only on established trails.

6. **Responses of mule deer to disturbance by persons afoot and in snowmobiles.** Freddy, D. J., Bronaugh, W.M., & Fowler, M.C. (1986) Wildlife Society Bulletin, 14: 63-68.

Abstract: Controlled disturbance of mule deer occurred from mid-January until early March in 1979-1980 within a 3-km2 portion of the Junction Butte State Wildlife Area in north-central Colorado. The study found that mule deer were disturbed more by persons on foot than by snowmobiles. Responses by deer to persons were longer in duration, involved more frequent running, and were greater in energy expenditure. Intensity of responses by deer was dependent upon distance between animals and disturbances. Minimizing all responses by deer would require persons afoot and snowmobiles to remain >334m and >470m from deer.

7. **Effects of disturbance by snowmobiles on heart rate of captive white-tailed deer**. Moen, A., N. (1982) New York Fish and Game Journal, 29(2), 176-186.

Abstract: Captive white-tailed deer exhibited increased heart rates in response to controlled tests of the effect of disturbance by snowmobiles conducted from December through March. Initial heart rate responses to the starting of a snowmobile and responses to its moving by indicated that deer can react to stimuli without changes in their overt behavior. When the snowmobile circled the pen, the deer showed greater heart rate and behavioral responses. Other deer in the yard also showed greater fright responses when snowmobiles approached them directly, versus when snowmobiles moved tangentially to their activity area. Moen concluded that, the increase in heart rate and additional movements caused by encounters with snowmobiles increase rather than decrease energy expenditures by deer. Such increases have potential to affect productivity of individuals and, ultimately, of the population. Management should take into consideration the basic biological characteristics of wildlife species. It is evident that disturbance by snowmobiles is contrary to long-term energy-conservation adaptations of white-tailed deer.

8. **Snowmobile impacts on the natural environment.** Aasheim, R. (1980) R.L. Andrews and P.F. Nowak, (eds.) Off-road Vehicle Use: A management challenge conference. Ann Arbor, MI.

Abstract: Snowmobiling and its impacts on natural environments in Montana are described. Studies of impacts on deer and elk have produced conflicting results, but there is little doubt that additional stress on poor-condition animals in winter is undesirable. Animals accustomed to humans are less affected by snowmobiles than animals in more remote areas. Effects on small mammals and possible effects of packed snowmobile trails are discussed.

9. **Snowmobile effects on movements of white-tailed deer: A case study.** Eckstein, R. G., O'Brien, T.F., Rongstad, O.J., & Bollinger, J.G. (1979) Environmental Conservation, 6: 45-51. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0034.pdf

Abstract: Data showed that snowmobile activity had no significant effect on home-range size, habitat use, or daily activity patterns of white-tailed deer wintering in Wisconsin. Snowmobile activity did cause some deer to leave the immediate vicinity of the snowmobile trail. Darkness appeared to decrease reaction to disturbance. Deer appeared to react more to a person walking/skiing than on snowmobiles.

10. **Response of white-tailed deer to snowmobiles and snowmobile trails in Maine.** Richens, V. B., & Lavigne, G. R. (1978) Canadian Field-Naturalist, 92(4), 334-344. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-003.pdf

Abstract: White-tailed deer response to snowmobiles seemed dependent on the deer's apparent security. Animals in the open or in hardwood stands tended to run when approached by snowmobile. Deer in softwood stands, which provide more cover, showed a greater tendency to stay when approached. A significantly greater number of deer ran from a person walking than from a person on snowmobile.

11. **Winter response of deer to snowmobiles and selected natural factors.** Lavigne, G. R. (1976) University of Maine. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-003A.pdf

Abstract: Deer responses to snowmobiles and selected natural factors were studied during winters of 1972/73. Use of snowmobile trail was significantly correlated with deer density and winter severity. Most movements on snowmobile trails were for short distances. Disturbance of deer by snowmobiles did not cause them to abandon preferred bedding and feeding sites. Snowmobile trails enhanced deer mobility and probably reduced their energy expenditure.

12. **Effects of snowmobiles on white-tailed deer**. Dorrance, M., & Savage, P.J. (1975) Journal of Wildlife Management, 39(3): 563-569. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-006.pdf

Abstract: The effects of snowmobiles on white tailed deer were studied in Minnesota during 1973 and 1974. Study areas were in St. Croix State Park, where numbers of snowmobiles per day averaged 10 on weekdays and 195 on weekends, and in Mille Lacs Wildlife Management Area, where snowmobiling was prohibited except by project personnel. Home range size, movement, and distance from radio-collared deer to the nearest trail increased with snowmobile activity at Mille Lacs, but remained unchanged at St. Croix. Numbers of deer along a l0-km trail decreased as snowmobile traffic increased at St. Croix. Light snowmobile traffic caused the displacement of deer from areas immediately adjacent to trails at St. Croix; thereafter, increased snowmobile traffic caused no additional response. Deer returned to areas along trails within hours after snowmobiles ceased at St. Croix. Deer responded to very low intensities of intrusion by man and vehicles.

13. **Effect of snowmobile noise and deer and rabbits in their natural habitat**. Bollinger, J. (1974)

Abstract: The behavioral patterns of deer and rabbits before, during, and after extensive snowmobile activities were studied. The data gathered was used to assess the noise wildlife levels associated with various behavior patterns, and to assess the noise levels generated by different snowmobile uses on various types of terrain. Additional objectives were to determine the effects snowmobile noise and activity had on the home range of deer and rabbits and their seasonal movements; to determine reactions these animals had to men in the area not using snowmobiles but equipped with skis and snowshoes; and to determine if there was a difference in predator behavior in areas where snowmobiles were used versus those where no vehicles were operated. The research team was unable to detect severe or negative animal reactions to the noise generated by the vehicles. Conclusions of the study indicate that the deer and rabbits were not forced to move out of their normal home ranges, nor did they seek shelter or remain stationary with fright while snowmobiles were being operated. The only negative effect determined was that the animals did increase their movement during extensive vehicle use periods. Researchers were unable to determine whether it was the noise, physical presence, or both that caused the disturbance.

14. **Effects of snowmobiles on the movements of white-tailed deer in Northern Wisconsin.** Eckstein, R. G., & Rongstad, O.J. (1973) Proceedings of the Midwest Fish and Wildlife Conference.

Abstract: Studies in northern Wisconsin evaluated the effects of snowmobile use on white-tailed deer in wintering yards. Movements and activities of tele-metered deer were compared between a yard receiving snowmobile use and one with no use. Some deer showed avoidance of snowmobile trails while machines were present, but no significant changes in home range size or daily movement patterns were observed.

Elk

1. **Wildlife Responses to Motorized Winter Recreation in Yellowstone**. White, P.J., Davis, T., & Borkowski, J. (2005) Yellowstone Center for Resources & Montana State University. . http://www.nps.gov/yell/parkmgmt/upload/winterrec05.pdf

Abstract: This study monitored the behavioral responses of bison (*Bison bison*), elk (*Cervus elaphus*), and trumpeter swans (*Olor buccinator*) to motorized winter recreation by repeatedly surveying seven groomed or plowed road segments in Yellowstone National Park during December 2004 through March 20005. The study sampled >2,100 interactions between vehicles and wildlife groups and used multinominal logits models to identify conditions leading to behavioral responses. Responses by these wildlife species to over-snow vehicles were relatively infrequent, short in duration, and of minor to moderate intensity, with >81% categorized as no apparent response or look/resume activities, 9% attention/alarm, 7% travel, and 3% flight or defense. Analyses of similar data collected during 1999-2004 indicated the likelihood of active responses by wildlife increased significantly if (1) wildlife were on or near roads, (2) more vehicles were in a group, (3) wildlife groups were smaller, (4) ungulates were in meadows instead of forest or geothermal habitats, (5) interaction times increased, (6) wildlife were traveling instead of resting, and (7) humans dismounted vehicles and/or approached wildlife. The likelihood of an active response by bison or elk decreased as cumulative visitation increased, suggesting that these ungulates habituated somewhat to motorized recreation. There was no evidence of population-level effects to ungulates from motorized winter use because estimates of abundance either increased or remained relatively stable during three decades of motorized recreation prior to wolf colonization in 1998. **Thus, we suggest that the debate regarding the effects of motorized recreation on wildlife is largely a social issue as opposed to a wildlife management issue.** The likelihood of active responses by wildlife can be diminished by (1) restricting travel to predictable routes and times, (2) reducing the number of vehicles in groups, (3) reducing the number and length of stops to observe wildlife, (4) stopping vehicles at distances >100 meters, and (5) preventing human activities away from vehicles.

2. **Bison and Elk Responses to Winter Recreation in Yellowstone National Park.** Hardy, A.R. (2001) Montana State University master's thesis.

Abstract: The National Park Service (NPS) is tasked with protecting wildlife and providing public access to parklands; winter recreation in Yellowstone National Park (YNP) has challenged NPS managers to balance this dual mandate. This study addresses bison and elk responses to winter recreation in the Upper Madison River drainage of YNP. Using data on weather; winter recreation activity; elk and bison distribution, behavior, abundance, and fecal stress hormone (glucocorticoid) levels collected during the winters of 1998 – 1999 and 1999 – 2000, I developed models to analyze if if variables related to winter recreation contributed to bison and elk distribution, behavior, and stress hormone levels responses. As distance between human activities and bison and elk decreased, behavioral responses increased. Both species behaviorally responded more often to people off-trail than to people on trails ($P<0.001$ for both species), and these activities prompted more behavioral responses than activities on roads. Elk were farther from the road ($P=0.092$) after exposure to >7,500 cumulative vehicles entering the West Yellowstone gate. Elk residing along the road segment with the greatest amount of oversnow vehicle (OSV) activity had higher stress levels (unknown elk: $P<0.001$; collared cow elk: $P=0.004$) and may have been displaced from habitat along the road (distance: $P=<0.001$; numbers sighted: $P=0.082$) compared to elk residing along the less-traveled segment. Collared cow elk stress levels increased ($P=0.057$) while the probability of bison and elk behaviorally responding to human activities on the road decreased ($P=0.001$ for both species) as daily vehicles entering the West Yellowstone gate increased. The predictability and frequency of OSV activities facilitated habituation to the majority of the winter recreation activities. Abundance estimates indicated populations of wintering bison increased and wintering elk remained stable over 20 years. Despite varying responses to increased winter visitation since the late 1970s, bison

and elk return to winter in the same area each year, coexisting with winter recreation without incurring losses at the population level.

3. **Effects of Winter Recreation on Elk.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 17-30. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Groomed routes are likely to have impacts similar to those of primary transportation routes and scenic routes (particularly if they are located in low-elevation areas and along river corridors), depending on the level of human use. Groomed routes may provide an energy efficient travel route for elk, but may also do the same for predators of elk. Human activity in backcountry areas is likely to be less predictable than in other motorized recreation areas and, therefore, has more potential to create flight response in individual elk or groups of elk. Motorized use of these areas is likely to occur over a less-confined area than transportation routes, potentially increasing the area of disturbance or displacement of elk. This type of recreation usually occurs in higher elevation, deep-snow areas and so may impact only scattered groups of adult males.

Management Guidelines: Avoid placing transportation and motorized routes in low-elevation, low-snow, riparian, and open habitats favored by elk. Where this is necessary, attempt to occasionally move the route away from those areas and through denser timber or areas with adequate hiding cover. Avoid creating road-side barriers that may prevent elk from crossing roads or trails or that may trap animals along the route.

4. **Ungulates effects of recreation on Rocky mountain wildlife: A review for Montana.** Canfield, J. E., Lyon, L.J., Michael, H.J. & Thompson, M.J. (1999) Montana Chapter of the Wildlife Society.

Abstract: Ungulates provide a large percentage of the recreational opportunities for wildlife enthusiasts in the State of Montana. Hunting, wildlife viewing, and photography generate economic benefits in excess of $450 million annually. However, recreational activities have the potential not only to displace ungulates to private land where they may cause damage, but also to have negative direct and indirect effects to the populations themselves. During winter, many ungulates are seasonally confined to restricted geographic areas with limited forage resources. In these conditions, physiological adaptations and behavioral adaptations tend to reduce energy requirements. Despite lowered metabolic and activity rates, most wintering ungulates normally lose weight. Responses of ungulates to human recreation during this critical period range from apparent disinterest to flight, but every response has a cost in energy consumption. Snowmobiles have received the most attention compared to other wintertime disturbances, and the majority of reports dwell on negative aspects of snowmobile traffic.

However, snowmobiles appear less distressing than cross-country skiers, and for several ungulate species, the greatest negative responses were measured for unpredictable or erratic occurrences. In addition to increasing energy costs for wintering animals, recreational activity can result in displacement to less desirable habitats, or in some situations, to tolerance of urban developments. Tendencies to habituation vary by species, but habituated ungulates are almost always undesirable.

Managers can provide an important contribution to energy conservation by reducing or eliminating disturbance of wintering ungulates and restricting recreational use of spring ranges that are important for assuring recovery from winter weight loss. During summer, the biological focus for ungulates includes restoring the winter-depleted body condition and accumulating new fat reserves. In addition, females must support young of the year and males meet the energy demands of horn and antler growth. The potential for impacts increase and options for acquiring high quality nutrition, with the least possible effort, decline as the size of the area affected by recreationists expands to fill an increasing proportion of summer range. Disturbance of the highly productive seeps and wet sites may cause animals to withdraw to less productive areas. In addition, ungulates may be especially vulnerable to disturbance around special habitat features, such as salt licks. Persistently high levels of recreational use and the proximity to human population centers is predicted to impact reproductive performance of ungulate populations, but little direct research at this level of disturbance has been reported. Recreational traffic on and off roads has been linked with high rates of establishment and spread of noxious weeds in wildlife habitat.

The importance of summer range to most ungulate populations has gone unrecognized for many years. It is apparent, however, that managers can contribute substantially to the health, productivity, and survival of these populations by reducing human disturbances to summering animals. Big game hunting has more immediate effects on ungulate population densities and structures than any other recreational activity. Hunting season security and management affects short and long term hunting opportunities. Managers of public lands control only a few of the potential variables that contribute to security; including retention of important vegetative cover, travel management, and enforcement of travel regulations. There is a strong relationship between adequate security and predicted buck/bull carryover, but excessive hunter numbers will overwhelm any level of security. Hunting also has the potential to negatively affect herd productivity as mature males are lost from populations. Violations of ethical considerations including the concept of "fair chase" and the perception of the "sportsman" in the public mind, can increase ungulate vulnerability as well as influence social acceptance of the sport of hunting. Pursuit of pronghorns with ORVs and killing of trophy animals within game farm enclosures are presented as ethical violations.

5. **Elk responses to disturbance by cross country skiers in Yellowstone National Park.** Cassirer, E. F., Freddy, D.J. & Abies, E.D. (1992) Wildlife Society Bulletin 20: 375-381.

Abstract: Radio marked elk were intentionally disturbed by groups of people walking or skiing directly into their location. Disturbance resulted in displacement of elk and increased energy expenditure. Upon disturbance, distances moved were 1,675 m, and were related to distance to topographic barriers. The elk seemed to use ridges as primary cover and stands of trees secondarily, after they had gone over a ridge. Elk in this study had a low tolerance for disturbance by people on foot or skis. Disturbance caused temporary displacement of the elk.

Elk generally returned after people left the area, however, it is believed that this tendency may decline with repeated disturbances. The energy expended moving away from skiers represented approximately 5.5% of an estimated average daily expenditure of 6,035 kcal for elk in winter and is more than the normal estimated daily energy expenditure for movement.
Researchers believe that restricting cross-country skiers to locations >650m from elk wintering areas would probably minimize displacement of most non habituated elk. Skiers would likely have to remain at distances of >1,700m to completely avoid disturbing elk. The amount of winter range used by skiers and the number of days involved seemed to have more of an effect on elk than skier numbers. Therefore, when skier activity is located on elk wintering range it was recommended that concentrating use in sites with abundant topographic relief, and providing security areas in drainages adjacent to those where skiing occurs might minimize the added energy costs and displacement of elk.

6. **How off-highway vehicles affect elk.** Laing, M. E. (1992). National Off-Highway Vehicle Conservation Council: 1-3 http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0013-OHV%20effect%20on%20elk.pdf

Abstract: A NOHVCC Fact Sheet summarizing four different studies by different researchers in different regions of the western U.S, revealing varying responses. Generally, habituation to predictable

disturbances is commonly observed, and ATV/motorcycle traffic is not especially or uniquely disturbing when compared with other types of disturbances. The bibliography cites these four studies only.

7. **Influence of Nordic skiing on distribution of moose and elk in Elk Island National Park, Alberta.** Ferguson. M.A.D., & Langvatn, R. (1985) Canadian Field Naturalist, 96: 69-78.

Abstract: Effects of cross-country skiing on distribution of Moose and Elk during winter were studied on Elk Island National Park, Alberta. Aerial observations and track and pellet-group counts provided indices to distribution that could be related to trail location and/or use. Cross-country skiing influenced the general over winter distribution of Moose but not of Elk. Both species, however, tended to move away from areas near heavily-used trails during the ski season (January-March). Day to day movements away from trails occurred after the onset of skiing, but such displacement did not increase with the passage of additional skiers.

8. **Snowmobile impacts on the natural environment.** Aasheim, R. (1980) R.L. Andrews and P.F. Nowak, (eds.) Off-road Vehicle Use: A management challenge conference. Ann Arbor, MI.

Abstract: Snowmobiling and its impacts on natural environments in Montana are described. Studies of impacts on deer and elk have produced conflicting results, but there is little doubt that additional stress on poor-condition animals in winter is undesirable. Animals accustomed to humans are less affected by snowmobiles than animals in more remote areas. Effects on small mammals and possible effects of packed snowmobile trails are discussed.

9. **Telemetered heart rate of three Elk as effected by activity and human disturbance.** Ward, A. L., & Cupal, J. J. (1980) U.S. Forest Service, Fort Collins, Colorado.

Abstract: The effects of human disturbances on elk in Wyoming were studied during 1975/76. Two adult cows and one yearling male were fitted with heart rate monitors. Teams observed and encountered the elk 344 times to ascertain the effects of different stimuli. Positive heart and flight reactions were recorded. Elk responded most strongly to sonic booms, gunshots, and people on foot. Elk seldom reacted when approached by an OHV.

Goats / Mountain

1. **Effects of Winter Recreation on Mountain Goats.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 87-96. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Because of the remote and rugged nature of goat wintering habits, recreational use of such areas is unlikely. Because mountain goats are sensitive to loud noises, snowmobiles and helicopters could affect their behavior depending upon the proximity and duration of the disturbance. In most cases, it appears that wilderness designation and area use limitations have adequately protected mountain goat habitats from motorized-related disturbances in the Greater Yellowstone Area. Because mountain goat winter range is inaccessible and precipitous, goats and recreationists are not often coming into conflict. For recreation, humans tend not to seek the combination of rocky, rugged terrain, and low-snow conditions required for by mountain goats. Rather, snowmobilers and skiers prefer deep snow conditions, which are typically avoided by goats.

Management Guidelines: No immediate management recommendations are offered.

Lynx

1. **Canada Lynx Conservation Assessment and Strategy.** Interagency Lynx Biology Team (2013) 3rd edition. USDA Forest Service, USDI Fish and Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Forest Service Publication R1-13-19, Missoula, MT. http://www.fs.fed.us/biology/resources/pubs/wildlife/LCAS_revisedAugust2013.pdf

Synopsis of major changes from the previous edition: This edition of the LCAS provides a full revision, incorporating all prior amendments and clarifications, substantial new scientific information that has emerged since 2000 including related parts of the Lynx Recovery Plan Outline, as well as drawing on experience gained in implementing the 2000 LCAS. The document has been reorganized and condensed to improve readability and reduce redundancy.

Chapter 3, Lynx Geographic Areas, has been substantially revised to incorporate new information about lynx and lynx habitat. The map (Fig. 3.1) has also been updated.

Chapter 4, formerly titled Risk Factors, is here retitled as Anthropogenic Influences on Lynx and Lynx Habitat. The anthropogenic influences are grouped into 2 tiers based on the potential magnitude of effects on lynx and their habitats. For each anthropogenic influence, there is an explanation of how it may influence key drivers of lynx population dynamics: the snowshoe hare (Lepus americanus) prey base, direct mortality of lynx, and the risks associated with small population size.

The chapters that formerly described Planning Area and Project Level were eliminated in this edition. The original intent was to provide the perspective of a multi-tier spatial hierarchy in discussing status, trends, and concerns relative to lynx and lynx habitat. In retrospect, however, these two chapters were redundant to material already presented in the previous chapters.

Chapter 5, Conservation Strategy, incorporates concepts from the Canada Lynx Recovery Outline (U.S. Fish and Wildlife Service 2005). Specifically, conservation efforts for lynx are not to be applied equally across the range of the species, but instead more focus is given to high priority areas: the core areas. Further, we combined secondary areas and peripheral areas (which were also identified in the recovery outline) into one category, because they have similar characteristics and management recommendations. The intent is to place more emphasis on protection of the core areas, which support persistent lynx populations and have evidence of recent reproduction, and less stringent protection and greater flexibility in secondary/peripheral areas, which only support lynx intermittently. Chapter 5 presents conservation measures only for those anthropogenic influences that are within the authority of the federal agencies, and identifies areas where they should be applied.

Guidance provided in the revised LCAS is no longer written in the framework of objectives, standards, and guidelines as used in land management planning, but rather as conservation measures. This change was made to more clearly distinguish between the management direction that has been established through the public planning and decision-making process, versus conservation measures that are meant to synthesize and interpret evolving scientific information.

2. **Southern Rockies Lynx Management Direction – Record of Decision**. USDA Forest Service (2008) National Forests in Colorado and southern Wyoming http://www.fs.fed.us/r2/projects/lynx/documents/record_of_decision.pdf

Summary of the decision: The Forest Service is charged with managing various renewable resources so that they are utilized in the combination that will best meet the needs of the American people, with due consideration given to the relative values of the resources, and without impairment of the productivity of the land (Multiple Use Sustained Yield Act of 1960). Under the Endangered Species Act, the agency is required to use its authorities to conserve threatened and endangered species and the ecosystems upon which they depend. In this decision, I consider how to amend Land and Resource Management Plans (Plans) to add consistent management direction that will conserve the Canada lynx (*Lynx canadensis*), a species listed as threatened under the Endangered Species Act, while at the same time allowing management and use of other natural resources in the Southern Rocky Mountains.

I have selected Alternative F-modified (Attachment 1). With this decision, the eight Land and Resource Management Plans (Plans) listed above are amended to incorporate the goal, objectives, standards and guidelines, and monitoring requirements of Alternative F-modified. My decision provides management direction that contributes to conservation of the lynx in the Southern Rocky Mountains, meets the Purpose and Need, responds to public concerns, and incorporates the terms and conditions contained in the U.S. Fish and Wildlife Service's Biological Opinion. My decision is consistent with applicable law, regulation and policy.

This decision supersedes the 2006 Lynx Conservation Agreement in the Southern Rockies Lynx Amendment area. The White River and Medicine Bow National Forests previously completed revisions of their Plans (in 2002 and 2004, respectively) and incorporated management direction for lynx. By amending all eight Plans in the Southern Rockies, this decision assures consistent management direction. The U.S. Fish and Wildlife Service's 2008 Biological Opinion for this amendment supersedes previous Biological Opinions for lynx that were issued for the White River Revised Plan, Medicine Bow Revised Plan, and Rio Grande MIS Amendment.

Over-the-snow winter recreation (p 13-14): Lynx have very large feet relative to their body size, providing them with a competitive advantage over other carnivores in deep snow. The LCAS recommended two objectives and two standards relating to winter dispersed recreation, which are reflected under Alternative B as Objectives *HU O1 and HU O3,* and Standards *HU S1 and HU S3*. All alternatives contain Objectives *HU O1* and *HU O3* that discourage expansion of snowcompacting human activities. All alternatives would allow existing special use permits and agreements to continue.

In comments on the Draft EIS, some people said they thought allowing no net increase in groomed or designated routes was insufficient, and asked that no dispersed over-the snow use be allowed off groomed or designated trails. Some recommended that the management direction be in the form of a standard, not a guideline.

Other people said standards related to over-the-snow use should be removed. They said there is no evidence to show that coyotes and other predators use packed snow trails to compete with lynx for prey, and the amount of compaction created by snowmobiles is insignificant compared to the compaction created naturally by the weather. They were concerned that if such language was introduced into Plans, it could be difficult to change and would restrict the places where snowmobiling is allowed. Others wanted an allowance made to increase snowmobile use.

Multi-species predator and prey relationships in the boreal forest are complex. The degree to which lynx and coyotes compete for snowshoe hares in the western United States is unknown. In some regions and studies, coyotes were found to use supportive snow conditions more than expected. For example, Bunnell et al. (2006) reported that the presence of snowmobile trails was a highly significant predictor of coyote activity in deep snow areas, and suggested that coyotes may use compacted routes to access lynx habitat and compete with lynx for snowshoe hare prey. On the other hand, Kolbe et al. (2007) found that compacted snow routes did not appear to enhance coyotes' access to lynx and hare habitat, and that there was little evidence that compacted snowmobile trails increased competition between coyotes and lynx during winter in Montana. In their final listing rule (2000b) and remanded rule (2003), FWS concluded there is no evidence that competition exists that may exert a population-level impact on lynx, although adverse effects on individual lynx are possible depending on the situation (USDI Fish and Wildlife Service 2008).

Current research indicates that prohibiting snow-compacting activities or reducing dispersed recreation use would be unwarranted. At the same time, an alternative to drop all direction limiting snow compaction was not developed in detail, because snow compaction may affect individual lynx.

I decided to include guideline *HU G10* in Alternative F-modified, which says that designated over-the-snow routes or play areas should not expand outside of the baseline areas of consistent snow compaction, unless it serves to consolidate use and improve lynx habitat. There may be some cases where expansion of over-the-snow routes would be warranted and acceptable, or where research indicates there would be no harm to lynx, and this guideline provides the flexibility to accommodate those situations. Guideline *HU G12* limits access for non-recreation uses to designated routes.

The U.S. Fish and Wildlife Service concluded the Objectives *HU O1* and *O3* and Guidelines *HU G10* and *G12* would maintain habitat effectiveness for lynx by limiting the expansion of compacted snow routes. This conclusion will be tested through monitoring required as part of this decision.

3. **Northern Rockies Lynx Management Direction – Record of Decision**. USDA Forest Service (2007) National Forests in Montana and parts of Idaho, Wyoming, and Utah http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5277399.pdf

Summary of the decision: We have selected Alternative F, Scenario 2 as described in the Northern Rockies Lynx Management Direction Final Environmental Impact Statement (FEIS) (pp. 35 to 40), with modifications. We modified Alternative F, Scenario 2 and incorporated the U.S. Fish and Wildlife Service (FWS) Terms and Conditions (USDI FWS 2007), where applicable, into the management direction – see Attachment 1- hereafter called the *selected alternative*. We determined the selected alternative provides direction that contributes to conservation and recovery of Canada lynx in the Northern Rockies ecosystem, meets the Purpose and Need, responds to public concerns, and is consistent with applicable laws and policies. In the FEIS we analyzed six alternatives in detail and two scenarios for Alternative F. Of those, we determined Alternative F Scenario 2 is the best choice. With this decision, we are incorporating the goal, objectives, standards, and guidelines of the selected alternative into the existing plans of all National Forests in the Northern Rockies Lynx Planning Area – see Figure 1-1, FEIS, Vol. 1 Tables 1-1 and 1-2.

The direction applies to mapped lynx habitat on National Forest System land presently **occupied** by Canada lynx, as defined by the *Amended Lynx Conservation Agreement between the Forest Service and the FWS* (USDA FS and USDI FWS 2006). When National Forests are designing management actions in **unoccupied** mapped lynx habitat they should consider the lynx direction, especially the direction regarding linkage habitat. If and when those National Forest System lands become occupied, based upon criteria and evidence described in the Conservation Agreement, the direction shall then be applied to those forests. If a conflict exists between this management direction and an existing plan, the more restrictive direction will apply.

The detailed rationale for our decision, found further in this document, explains how the selected alternative best meets our decision criteria. Those decision criteria are: 1) meeting the Purpose and Need to provide management direction that conserves and promotes the recovery of Canada lynx while preserving the overall multiple use direction in existing plans; 2) responding to the issues; and 3) responding to public concerns.

Management direction related to human uses: Over-the-snow winter recreation (pp. 22-25)
Lynx have very large feet in relation to their body mass, providing them a competitive advantage over other carnivores in deep snow. Various reports and observations have documented coyotes using high elevation, deep snow areas (Buskirk et al. 2000). Coyotes use open areas because the snow is more compacted there, according to research conducted in central Alberta (Todd et al. 1981). In another study in Alberta, coyotes selected hard or shallow snow more often than lynx did (Murray et al. 1994).

The LCAS recommended two objectives and two standards relating to winter dispersed recreation. These are reflected in Alternative B, Objectives HU O1 and HU O3, and Standards HU S1 and HU S3. In Alternative B, Standard HU S1 would maintain the existing level of groomed and designated routes. All action alternatives contain Objectives HU O1 and HU O3 that discourage expanding snow-compacting human activities. Alternatives B, C, and D contain Standard HU S1 that would allow existing over-the-snow areas to continue but not expand into new, un-compacted areas. Alternative E, the DEIS preferred alternative, contains Guideline HU G11 that discourages the expansion of designated over-the-snow routes and play areas into uncompacted areas. All alternatives would allow existing special use permits and agreements to continue.

In comments on the DEIS some people asked that no dispersed over-the-snow use be allowed off groomed or designated trails and areas, saying the no net increase in groomed or designated routes did not go far enough. Others said the management direction should be in the form of a standard, not a guideline.

Some people said standards related to over-the-snow use should be removed. They said there is no evidence to show that coyotes and other predators use packed snow trails to compete with lynx for prey, and the amount of compaction created by snowmobiles is insignificant compared to the compaction created naturally by the weather. They were particularly concerned that if such language was introduced into plans, it could be difficult to change, incrementally restricting the places where snowmobiling is allowed. Others wanted an allowance made to increase use. These comments were considered for management direction – see FEIS Vol. 1 pp. 90-93.

In their comments on the DEIS the FWS agreed it is prudent to maintain the status quo and restrict expansion of over-the-snow routes until more information is available because of the possibility that, over time, unregulated expansion could impair further conservation efforts. They also said current, ongoing research in Montana may shed some information on the effects of snow compaction on lynx. They suggested careful consideration of the most recent information and the reality of possible impairment of options for the future. They suggested considering language that could provide more guidance on conditions where the expansion of over-the-snow routes would be warranted and acceptable.

We reviewed the results of research conducted since the DEIS was released. In northwestern Montana (within the northern lynx core area) Kolbe et al. (in press) concluded there was “little evidence that compacted snowmobile trails increased exploitation competition between coyotes and lynx during winter on our study area.” Kolbe et al. (in press) suggested that compacted snow routes did not appear to enhance coyotes’ access to lynx and hare habitat, and so would not significantly affect competition for snowshoe hare. They found that coyotes used compacted snow routes for less than 8 percent of travel, suggesting normal winter snow conditions allowed access by coyotes, regardless of the presence or absence of compacted snow routes. Kolbe was able to directly measure relationships between coyotes, compacted snow routes and snowshoe hare in an area that also supports a lynx population (USDI FWS 2007). In this study coyotes primarily scavenged ungulate carrion that were readily available while snowshoe hare kills comprised only three percent of coyote feeding sites (Kolbe et al. in press).

In the Uinta Mountains of northeastern Utah and three comparative study areas (Bear River range in Utah and Idaho, Targhee NF in Idaho, Bighorn NF in Wyoming) Bunnell (2006) found that the presence of snowmobile trails was a highly significant predictor of coyote activity in deep snow areas. From track surveys it was determined the vast majority of coyotes (90 percent) stayed within 350 meters of a compacted trail and snow depth and prey density estimates (snowshoe hares and red squirrels) were the most significant variable in determining whether a coyote returned to a snowmobile trail (Bunnell 2006). Of the four study areas recent lynx presence has only been documented on the Targhee NF. Bunnell indicated that "circumstantial evidence" suggested the existence of competition.

To date, research has confirmed lynx and coyote populations coexist, despite dietary overlap and competition for snowshoe hare, the primary prey of lynx, and alternate prey species. In some regions and studies, coyotes were found to use supportive snow conditions more than expected, but none confirm a resulting adverse impact on lynx populations in the area. The best scientific information (Kolbe's study) is from an occupied core area within our planning area. Radio-collared lynx and coyotes were monitored in this study, unlike the Bunnell study. This area is occupied by both lynx and coyotes and the study concludes coyotes did not require compacted snow routes to access winter snowshoe hare habitat. Based on this information, we reevaluated management direction related to over-the-snow activities. An alternative to prohibit all snow-compacting activities or to limit dispersed use was evaluated, but not considered in detail because current research indicates this level of management direction is unwarranted (USDI FWS 2000a; FEIS, Vol. 1, Appendices O and P).

An alternative to drop all direction limiting snow compaction was not developed in detail because there is evidence competing predators use packed trails, suggesting a potential effect on individual lynx. We decided it was prudent to maintain status quo and not let over-the-snow routes expand. However, we also decided it was reasonable to retain the direction as a guideline in the selected alternative which can be used in project design. The intent is to follow management direction in guidelines. However, there may be some cases where expansion of over-the-snow routes would be warranted and acceptable, or where research indicates there would be no harm to lynx. Guidelines are better suited to adaptive management.

There is also no basis to establish any particular threshold of allowable increases. However, the selected alternative allows expanding winter recreation in some places where heavy public use existed in 1998, 1999, or 2000 – see Guideline HU G11.

The FWS concluded the Objectives HU O1 and O3, and Guideline HU G11 would be sufficient to maintain habitat effectiveness for lynx by limiting the expansion of compacted snow routes and this conclusion would be tested through monitoring required in this decision. The best information available has not indicated compacted snow routes increase competition from other species to levels that adversely affect lynx populations, and under the selected alternative the amount of areas affected by snow compacted routes would not substantially increase (USDI FWS 2007).

4. **The Effect of Snowmobile Trails on Coyote Movements Within Lynx Home Ranges.** Kolbe, J.A., Squires, J.R., Pletscher, D.H., and Ruggiero, L.F. (2007) Journal of Wildlife Management 71(5):1409–1418
https://www.researchgate.net/publication/43259710_The_Effect_of_Snowmobile_Trails_on_Coyote_Movements_Within_Lynx_Home_Ranges

Abstract: Coyotes (Canis latrans) and Canada lynx (Lynx canadensis) are sympatric throughout much of the lynx's southern range. Researchers and managers have suggested that the presence of compacted snowmobile trails may allow coyotes to access lynx habitat from which they were previously excluded by deep, unconsolidated snow. This could then allow coyotes to more effectively compete with lynx for snowshoe hares (Lepus americanus), the lynx's primary prey. We investigated how coyotes interacted with compacted snowmobile trails by conducting carnivore track surveys and by snow tracking adult coyotes (4 M, 8 F) in areas of western Montana, USA, with both documented lynx presence and recreational snowmobile use. Coyotes remained in lynx habitat having deep snow throughout the winter months. They used compacted snowmobile trails for 7.69% of their travel distance and traveled on them for a median distance of 124 m. Coyotes used compacted forest roads (5.66% of total travel) and uncompacted forest roads (4.62% of total travel) similarly. Coyotes did not travel closer to compacted snowmobile trails than random expectation (coyote x distance from compacted trails ¼ 368 m, random expectation ¼ 339 m) and the distance they traveled from these trails did not vary with daily, monthly, or yearly changes in snow supportiveness or depth. However, they strongly selected for naturally shallower and more supportive snow surfaces when traveling off compacted snowmobile trails. Coyotes were primarily scavengers in winter (snowshoe hare kills composed 3% of coyote feed sites) and did not forage closer to compacted snowmobile trails than random expectation. The overall influence of snowmobile trails on coyote movements and foraging success during winter appeared to be minimal on our study area. The results of this study will allow land managers to better assess the effects of snow-compacting activities on coyotes and lynx.

5. **Canada Lynx in the Great Lakes Region 2005 Annual Report.** Moen, R., Niemi, G., & Burdett, C.L. (2006) Report to the U.S.D.A. Forest Service, Minnesota Cooperative Fish and Wildlife Research Unit, and Minnesota Department of Natural Resources http://www.nrri.umn.edu/lynx/publications/2005_MN_LynxReport_v2.pdf

Executive Summary: We summarize the third year of a project on Canada lynx ecology in the Great Lakes region. The project is designed to address four major questions about this population of Canada lynx: distribution, habitat use, abundance, and persistence. In the first 33 months of this project we captured and deployed radiotelemetry collars on 32 Canada lynx. Each animal was located approximately biweekly after being collared when logistically feasible.

GPS collars have been deployed on 12 of the lynx in this project. Over 12,000 locations were obtained from GPS collars at the end of 2005. GPS collar locations will be fundamental to understanding movements and habitat use of Canada lynx. Ambient temperature and animal activity level is recorded by the collars indicating daily patterns in activity, and also shows how active an animal was when each GPS location was obtained.

Radiocollared females have had kittens in 2004 and 2005, and at least 5 of the 12 kittens known from den visits in 2005 survived until December 2005. Of the 2004 litters, 1 and possibly 2 of the known offspring were alive at the end of 2005. Of the 32 lynx radiocollared by December 31, 2005, 2 died in 2003 and no animals were recovered dead in 2004. We recorded the deaths of 14 radiocollared animals in 2005, one of which had died in 2004.

We finished the third year of surveys for snowshoe hare, the major prey species of Canada lynx. Permanent pellet plots were established throughout the SNF for snowshoe hare. Plots were distributed based on stratified random, systematic, and selective site selection strategies. Many stratified random plots had few or no pellets. The highest pellet density over two years of pellet surveys occurred in young red pine and young upland black spruce cover types. A mark-recapture experiment will make it possible to estimate density of snowshoe hares from pellet plots.

We continue to use the project website (www.nrri.umn.edu/lynx) to provide information to biologists and the general public. The website gets over 1,000 page requests per day. This website is a historical record of the project, lists project goals and accomplishments, and gives information and pictures of each lynx. The annual reports and other publications on the project are or will be available for download. Trail camera images were added to the website in 2005.

We begin the report with a brief chronological summary of Canada Lynx ecology in the Great Lakes region. The project has been supported by several agencies with some common deliverables and some deliverables that varied among agencies. To produce a cohesive, logically organized annual report, we describe the project in its entirety, and we indicate specific deliverables in Appendix 1. We first describe Canada lynx trapping and the deployment of radiotelemetry collars. The radiotelemetry program is very important because each of the major deliverables depends on telemetry data. Next, we address progress made on each of the major questions: 1) distribution, 2) habitat use, 3) abundance, and 4) persistence. Prey species surveys and other aspects of the project are also summarized.

We conclude main sections with the current status and future plans for each topic. Some of the questions will require several years of data collection which was built into the project master plan. With the number of Canada lynx now radiocollared and the number of locations available, data collected on this project were used to assist in management decisions in 2005.

6. **National Interagency Canada Lynx Detection Survey in Minnesota, Wisconsin, and Michigan.** Burdett, C., Lindquist, E., Moen, R., Niemi, J., & Route, B. (2006) Center for Water and Environment Natural Resources Research Institute – University of Minnesota, U.S.D.A. Forest Service – Superior National Forest, and Department of Interior National Park Service – Great Lakes Monitoring Network. http://www.nrri.umn.edu/lynx/publications/NRRI_TR-2006-29.pdf

Summary: A variety of non-invasive techniques including hair snagging, snow-tracking, and remote cameras can be used to monitor mammalian carnivores. The National Interagency Canada Lynx Detection Survey (NLDS) was a survey designed to detect lynx with a hair-snagging protocol applied throughout the conterminous U.S. range of lynx. Hare-snagging stations consisted of a scent lure, a carpet piece with nails to snag hair, and a pie tin to attract the cat's attention. We applied NLDS protocol in Superior and Chippewa National Forests in Minnesota, the Chequamegon and Nicolet National Forests in Wisconsin, and the Ottawa National Forest in Michigan. Mammalian species detected included black bears (*Ursus americanus*), bobcats (*Lynx rufus*), coyotes (*Canis latrans*), ungulates, and other canids. The NLDS did not detect lynx in the Great Lakes Geographic Area (GLGA) despite their likely presence on some of the Minnesota NLDS grids. We also opportunistically set up hair snagging stations in areas in Minnesota where we knew lynx were present to further test the efficacy of hair-snagging stations. We had limited success using hair snares to selectively sample lynx despite placing snares in areas regularly used by lynx. We suspect the detection probability for lynx hair-snagging surveys in the GLGA may be low and other survey techniques may prove more useful, particularly for localized selective sampling for lynx presence.

7. **Lynx Habitat Management Plan for DNR-Managed Lands.** Quade, C. & Minkova, T. (2006) Washington State Department of Natural Resources http://www.dnr.wa.gov/Publications/lm_ess_lynx_plan_final.pdf

Introduction: The Washington State Department of Natural Resources (DNR) manages more than 5 million acres of state land. Some of those lands are uplands within the range of the Canada lynx (Lynx canadensis) (Figure 1), a native cat that is listed as threatened with extinction—both in the state of Washington and under the federal Endangered Species Act.

Lynx habitat is forested, and most DNR-managed forests are managed using sustainable forest management practices to provide income for various state trust beneficiaries, including public schools, state universities, counties, and other public institutions. Forest management activities in Washington State are regulated by the state's Forest Practices rules, and DNR's forest management must comply with those rules.

This modified Lynx Habitat Management Plan (the 2006 Lynx Plan) was developed in response to the federal listing of the species (USFWS 2000). It revises the 1996 DNR Lynx Habitat Management Plan (WDNR 1996a), which had been developed in response to the state listing. This plan guides DNR's forest management activities to facilitate the creation and preservation of quality lynx habitat. It allows DNR to meet state and federal requirements for protecting lynx, while at the same time providing revenue through timber production and meeting its other land management obligations (i.e. recreation).

This chapter provides historical and management context and basic information about the Canada lynx natural history and distribution. The following chapters define categories of lynx habitat, outline DNR's implementation of the plan, and provide specific guidelines and provisions for monitoring and evaluation. A report on the implementation monitoring conducted for the period 1996-2004, in accordance with the 1996 Lynx Plan commitment, is presented in Appendix 1, and a report on the effectiveness monitoring conducted from 1997 through 2002 is presented in Appendix 2.

8. **Lynx and Other Carnivore Surveys in Wisconsin in Winter 2003-2004.** Wydeven, A.P., Wiedenhoeft, J.E., Schultz, R.N., & Boles. S. (2004) Wisconsin DNR and U.S. Fish and Wildlife Services – Region 3 Endangered Species Grant Program. http://www.dnr.state.wi.us/org/land/er/publications/reports/pdfs/LynxandOtherCarnivoreSurveysinWisconsininwinter2003-2004.pdf

Introduction: The Wisconsin DNR listed the Canada lynx (*Lynx canadensis*) as a state endangered species in 1973, but removed lynx from the list in 1997, due to lack of evidence of any potential for a breeding population within the state. The U.S. Fish and Wildlife Service listed the lynx as a threatened species within the contiguous Unites States on 24 April 2000. States that were thought to have lynx included Wisconsin, Michigan, Minnesota and 10 other states. There has not been any evidence of a breeding population of lynx in Wisconsin in the 1900's (Thiel 1987, Wydeven 1998). Lynx are occasionally observed in the state, and up to 1% of bobcat hunters and trappers reported lynx sign in Wisconsin (Wydeven 1998). Therefore there is a need to determine more precisely if lynx are occurring in Wisconsin, and if so, determine distribution and breeding status of lynx in the state.

The Wisconsin DNR has cooperated with the U.S. Fish and Wildlife Service to search for gray wolves (*Canis lupus*) using snow track surveys since 1979 (Wydeven et al 1995). These surveys have detected lynx in the past (Wydeven 1998, Wydeven et al 1995). Therefore these snow track surveys are being used to search for evidence of lynx in the state.

Results: A total of 3696.5 miles of track surveys were conducted by DNR trackers in 80 survey blocks in northern Wisconsin (Table1, Figure 1). Two sets of lynx tracks were detected in survey block 82, in Vilas County. The most abundant carnivores were fisher (*Martes pennanti)* which was detected at a rate of 16.0 per 100 miles of survey. The 4 canids were the next most abundant carnivores including coyotes (*Canis latrans* 14.1 / 100 miles), gray wolf (*Canis lupus* 9.4 / 100 miles), fox (*Vulpes vulpes & Urocyon cinereoargenteus* 8.8 /100 miles), and dog (*Canis familiaris* 8.0 / 100 miles). Rates of track detection were lower than 2003 for most carnivores, except wolves had increased, otter were similar, and the first observation of lynx tracks in 5 years.

Two probable lynx tracks were detected by Ron Schultz on 22 March 2004 in NW SW Section 36, T42N, R10E in Vilas County (Latitude 46. 0753 / Longitude 89.1981). It appeared that 2 lynx were traveling together. Schultz followed the tracks for about 2.1 miles. Snow conditions allowed only one good measurement, consisting of a minimum outline of 6.5 cm length and 7.1 cm width. Measurement of variable outline was 9 cm long by 10.2 cm wide. Urine samples were collected from snow, but could not be verified as lynx. Attempts were made for follow-up surveys and consideration was given to attempt trapping, but snow melted soon afterwards. It could not be determined if these 2 represented a female and her kitten or a male following a female; in either case this may represent the possibility of breeding lynx. Felid track observations included 97 bobcat (*Lynx rufus*) or 2.6/ 100 miles, 5 cats (*Felis catus)* at 0.1 / 100 miles, and 2 Canada lynx 0.1/ 100 miles. No cougar (*Puma concolor*) tracks were found and none have been detected during any previous years. Bobcat detection rate was less than 2003 (4.6 / 100 miles), but similar to 2002 (3.0/ 100 miles). Bobcat were detected in 41 survey blocks (51.2%).

More intense efforts to search for lynx were made in the Nicolet National Forest where lynx had been detected between 1993 and 1997 (Wydeven 1998). Two lynx were detected along 572.2 miles of survey route at a rate of 0.3 lynx per 100 miles (Table 2). This was the first detection of lynx in the Nicolet since 20 January 1997 (Wydeven 1998). Bobcats were detected at a rate of 6.1 bobcat / 100 miles, slightly higher than 2003, when 5.5 bobcat / 100 miles were found. Ratio of lynx:bobcat detection was 1:17.5.

Discussion: The 2 lynx found this year in northeast Vilas County were the first lynx detected since 1999 (Figure 2), when one was detected in western Douglas County along the Minnesota border (Wydeven et al. 1999). Four observations were detected in the Nicolet National Forest between 1993-1997 including: 17 February 1993, 28 January 1995, 1 March 1996, and 20 January 1997 (Wydeven 1998). All these observations were tracks of single animals, and close to Alvin in Forest County. The lynx track observation in 2004 was just to the west of the Nicolet Forest, and about 20 miles west of the sightings near Alvin.

The presence of 2 lynx together might indicate possibility of breeding activity. Normally only adult females and their offspring travel together, or adult males and females travel together during breeding season, but sometimes adult lynx hunt together (Mowat et al. 2000). The detection in late winter did not allow many follow-up surveys. Additional surveys will be done in the area next winter, and if lynx continue to be found in the area, livetrapping and radiocollaring will be attempted.

9. **Washington state recovery plan for the lynx.** Stinson, D.W. (2001) Washington Department of Fish and Wildlife, Olympia, Washington. http://wdfw.wa.gov/wlm/diversty/soc/recovery/lynx/finallynx.pdf

Executive Summary: The lynx (*Lynx canadensis*) is the rarest of three cat species native to Washington probably numbering fewer than 100 individuals in the state. Lynx have large feet and long legs that give them a competitive advantage in deep snow over other carnivores that might otherwise compete for habitat and prey. Lynx are largely dependent upon a single prey species, the snowshoe hare, but they also eat red squirrels, small mammals, birds, and carrion. Lynx are primarily associated with subalpine and boreal forest types in the mountains of north-central and northeastern Washington, and formerly occurred in the southern Cascades. Topographic relief gives these forests a patchy distribution which in turn affects their potential to support lynx.

Across most of their range in northern boreal forests, lynx undergo cyclic changes in abundance that lag 1 year behind snowshoe hare population cycles. This 10-year cycle in snowshoe hare abundance may occur in Washington with a reduced amplitude, but it has not yet been clearly demonstrated. The lynx's response to the hare cycle produces pulses of dispersing individuals that may travel long distances in search of suitable habitat. At these times, some lynx may immigrate to Washington from larger populations in British Columbia and Alberta. Immigration from northern populations, and dispersal between subpopulations in Washington may be essential to the long-term viability of Washington's lynx population.

Prior to 1947, lynx in Washington were classified a "predatory animal" with a bounty of $5. Lynx were trapped or hunted until 1991 when a decline was readily apparent. It now seems clear that the lynx population in Washington could not sustain perennial exploitation due to the fragmented nature of subalpine-boreal habitats, low density of snowshoe hares, and variable quality of habitat through time. The lynx was listed as a state threatened species in 1993, and became a Threatened species under the federal Endangered Species Act (ESA) in April 2000.

The major factors affecting habitat and the lynx population include forest management, fire and fire suppression, insect epidemics, and management of lynx harvest and habitats in southern British Columbia. Lynx are relatively tolerant of human activity, but recreational developments and roads with high traffic volumes may affect lynx movements. Anecdotal observations have fueled speculation that snow compaction on forest roads and trails may affect the degree to which lynx must compete with coyotes and other carnivores, but few data exist from which to draw conclusions about the affect on lynx. Most of the lynx habitat in six Lynx Management Zones is on federal lands (92%), and almost 40% is in wilderness, parks and other reserves. Petitions to list the lynx under the ESA, and the subsequent listing increased attention on lynx. The large proportion of habitat in national forests provides the opportunity for the U. S. Forest Service to manage for lynx at the ecosystem scale. The understanding of lynx harvest management has improved in recent years, providing British Columbia and Alberta the ability to prevent overharvests that could reduce the frequency of immigration to Washington. These factors may improve the prospects for the recovery of lynx populations in Washington.

Meaningful population based recovery objectives are not possible to formulate at this time due to the rudimentary knowledge of lynx population dynamics in southern boreal forests. Interim objectives to down-list the lynx to Sensitive involve consistent occupancy of most of the habitat (>75% of lynx analysis units) capable of supporting reproductive populations. Recovery objectives and maps will be revised as new information becomes available about the habitat and populations of lynx and hare in Washington.

10. **Canada Lynx Conservation Assessment and Strategy.** Ruediger, B., Claar J., Gniadek, S., Holt, B., Lewis, L., Mighton, S., Naney, B., Patton, G., Rinaldi, T., Trick, J., Vandehey, A., Wahl, F., Warren, N., Wenger, D., and Williamson, A. (2000) USDA Forest Service, USDI Fish & Wildlife Service, USDI Bureau of Land Management, and USDI National Park Service. Missoula, MT. http://www.fs.fed.us/r1/clearwater/terra_org/wildlife_07/t_e/canada_lynx/conservation_assessment_strategy%20.pdf

Executive Summary: **Purpose of this Document -** The Lynx Conservation Assessment and Strategy was developed to provide a consistent and effective approach to conserve Canada lynx on federal lands in the conterminous United States. The USDA Forest Service, USDI Bureau of Land Management, and USDI Fish and Wildlife Service initiated the Lynx Conservation Strategy Action Plan in spring of 1998.

The lynx was proposed for listing as a threatened species under the Endangered Species Act on July 8, 1998 (Federal Register Volume 63, No. 130). The final rule listing the contiguous United States Distinct Population Segment (DPS) was published on March 24, 2000 (Federal Register Volume 65, No. 58). In the final rule, the U.S. Fish and Wildlife Service concluded that the factor threatening the contiguous U.S. DPS of lynx is the inadequacy of existing regulatory mechanisms, specifically the lack of guidance for conservation of lynx in the National Forest Land and Resource Management Plans and the BLM Land Use Plans. This lack of guidance may allow or direct actions that cumulatively adversely affect the lynx.

Under provisions of the Endangered Species Act, federal agencies shall use their authorities to carry out programs for the conservation of listed species, and shall insure that any action authorized, funded, or carried out by the agency is not likely to jeopardize the continued existence of any threatened or endangered species or result in the destruction or adverse modification of critical habitat (16 USC 1536).

The conservation measures presented in this document were developed to be used as a tool for conferencing and consultation, as a basis for evaluating the adequacy of current programmatic plans, and for analyzing effects of planned and on-going projects on lynx and lynx habitat.

Guiding Principles: The conservation strategy must provide guidance that retains future options, provides management consistency, offers necessary flexibility, and ultimately will accomplish the objective of conserving the lynx. In the face of a high degree of scientific uncertainty, we relied on five guiding principles:

- *Use the best scientific information available about lynx*. We relied on information from research throughout the range of the species, recognizing that behavior and habitat use may be different in the southern portion of its range. We also incorporated information about the ecology of the primary lynx prey species, snowshoe hare, and an important secondary prey species, red squirrel. Where no information exists, we made assumptions or inferences, based on the collective experience and professional judgment of team members and other scientists.
- *Until more conclusive information concerning lynx management is developed, retain future options.* In some cases, this led us to recommend no increase in certain types of development within lynx habitat, even though the effects of current levels may be unknown. A conservative approach is prudent to avoid irrevocably committing resources that may ultimately prove to be important to the survival and/or conservation of lynx.
- *Integrate a consideration of natural ecological processes and landscape patterns, and explicitly consider multiple spatial scales*. A blending of the ecological process and species-centered approaches is more likely to maintain diversity, species viability, and sustainability.
- *Consider the habitat requirements of other wildlife species, including other forest carnivores*. A management plan that integrates recommendations for a variety of species is more likely to be feasible and to be successfully implemented.
- *Develop a useful, proactive plan to conserve lynx on federal lands.* Although analysis may consider all ownerships to provide context, conservation measures apply only to federal lands.

How the Document is Organized: Part I of the document provides an assessment of lynx status and risk. An overview of lynx ecology is presented first, followed by identification and description of risk factors. Lynx population status, habitat, and relevant risk factors are assessed for four spatial scales: range-wide, each of 5 geographic areas (Cascade Mountains, Northern Rocky Mountains, Southern Rocky Mountains, Great Lakes, and Northeast), planning unit, and home range. The assessment lays the conceptual and scientific foundation for Part II, the conservation strategy.

Part II contains recommended conservation measures that address each of the risk factors. The conservation measures are sorted into programmatic and project level objectives and standards. Additional sections provide guidance for analysis of effects and project conferencing and consultation, inventory and monitoring, and management priorities.

Lynx Habitat: Lynx occur in mesic coniferous forests that have cold, snowy winters and provide a prey base of snowshoe hare (Quinn and Parker 1987, Koehler and Brittell 1990, Koehler 1990, Koehler and Aubry 1994, Mowat et. al. 2000, McKelvey et. al. 2000*b*, Ruggiero et al. 2000*b*). In North America, the distribution of lynx is nearly coincident with that of snowshoe hares (McCord and Cardoza 1982, Bittner and Rongstad 1982). Lynx are uncommon or absent from the wet coastal forests of Canada and Alaska (Mowat et al. 2000).

Both snow conditions and vegetation type are important factors to consider in defining lynx habitat. Across the northern boreal forests of Canada, snow depths are relatively uniform and only moderately deep (100-127 cm or 39-50 inches) (Kelsall et al. 1977). Snow conditions are very cold and dry. In contrast, in the southern portion of the range of the lynx, snow depths generally increase, with deepest snows in the mountains of southern Colorado. Snow in southern lynx habitats also may be subjected to more freezing and thawing than in the taiga (Buskirk et al. 2000*b*). Crusting of snow may reduce the competitive advantage that lynx have in soft snow, with their long legs and low foot loadings (Buskirk et al. 2000*a*).

Vegetation types and elevations that provide lynx habitat include:

- Northeastern U.S.: Most lynx occurrences (88%) fell within Mixed Forest-Coniferous Forest-Tundra province; 77% of occurrences were associated with elevations of 250-500 m (820-2,460 ft) (McKelvey et al. 2000*b*). Lynx habitat includes coniferous and mixed coniferous/deciduous vegetation types dominated by spruce, balsam fir, pine, northern white cedar, hemlock, aspen, and paper birch.
- Great Lakes states: Most lynx occurrences (88%) fell within the Mixed Deciduous/Conifer Forest province (McKelvey et al 2000*b*). Lynx habitat includes boreal, coniferous, and mixed coniferous/deciduous vegetation types dominated by pine, balsam fir, black and white spruce, northern white cedar, tamarack, aspen, paper birch, conifer bogs and shrub swamps.
- Western U.S.: Most lynx occurrences (83%) were associated with Rocky Mountain Conifer Forest, and most (77%) were within the 1,500-2,000 m (4,920-6,560 ft) elevation zone (McKelvey et al. 2000*b*). There is a gradient in the elevational distribution of lynx habitat from the northern to the southern Rocky Mountains, with lynx habitat occurring at 2,440-3,500 m (8,000-11,500 ft) in the southern Rockies. Primary vegetation that contributes to lynx habitat is lodgepole pine, subalpine fir, and Engelmann spruce (Aubry et al. 2000). In extreme northern Idaho, northeastern Washington, and northwestern Montana, cedar-hemlock habitat types may also be considered primary vegetation. In central Idaho, Douglas-fir on moist sites at higher elevations may also be considered primary vegetation. Secondary vegetation that, when interspersed within subalpine forests, may also contribute to lynx habitat, includes cool, moist Douglas-fir, grand fir, western larch, and aspen forests. Dry forest types (e.g., ponderosa pine, climax lodgepole pine) do not provide lynx habitat.

Landscapes are more heterogeneous in terms of topography, climate, and vegetation in the southern portion of its range, as compared to the northern taiga, (Buskirk et al. 2000*b*). In the southern portion of its range, lynx populations exhibit large home range sizes, high kitten mortality due to starvation, and greater reliance on alternate prey, especially red squirrels, which is similar to characteristics of populations in the taiga during the declining or low phase of the snowshoe hare cycle (Koehler 1990, Apps 2000). This suggests the importance of designing management practices to maintain or enhance habitat for snowshoe hare and alternate prey such as red squirrel.

Snowshoe hares are the primary prey of lynx, comprising 35-97% of the diet throughout the range of the lynx (Koehler and Aubry 1994). Red squirrels have been shown to be an important alternate prey species, especially during snowshoe hare population lows (Koehler 1990, O'Donoughue 1997). Summer food habits of lynx have been poorly defined, but McCord and Cardoza (1982) indicated that the diet might include other species such as mice, squirrels and grouse. Lynx at the southern periphery of the range may prey on a wider diversity of prey because of differences in small mammal communities and lower average hare densities, as compared with northern taiga.

The common component of natal den sites appears to be large woody debris, either down logs or root wads (Koehler 1990, Mowat et al. 2000, Squires and Laurion 2000). These den sites may be located within older regenerating stands (>20 years since disturbance) or in mature conifer or mixed coniferdeciduous (typically spruce/fir or spruce/birch) forests (Koehler 1990, Slough *in press* cited in Mowat et al. 2000). Stand structure appears to be of more importance than forest cover type (Mowat et al. 2000).

Risk Factors: The lynx assessment includes a list of potential risk factors (Table 1). This is a thorough list of programs, practices, and activities that may influence lynx or lynx habitat, and may need to be addressed during conferencing or consultation. The risk factors are limited to those within the authority and jurisdiction of the federal land management agencies.

Risk factors were not ranked by priority of effects to lynx or lynx habitat. Risk factors may interact, and their relative importance may vary in different areas. Lynx population distribution, habitat components, and risk factors are described for four spatial scales: range-wide; geographic areas (Cascade Mountains, Northern Rocky Mountains, Southern Rocky Mountains, Great Lakes, and Northeast); planning area; and home range.

Conservation Measures: Part II of the document is the conservation measures. These were developed to address each risk factor, in order to conserve the lynx and to avoid or reduce adverse effects from the spectrum of management activities on federal lands.

Plans that incorporate the conservation measures, and projects that implement them, are generally not expected to have adverse effects on lynx, and implementation of these measures across the range of the lynx is expected to lead to conservation of the species. However, because it is impossible to provide standards and guidelines that will address all possible actions, in all locations across the broad range of the lynx, project specific analysis and design also must be completed.

The conservation measures will likely be implemented through two scales of decision-making: programmatic and project planning. Programmatic plans provide broad direction for management activities by establishing goals, objectives, desired future condition statements, standards, guidelines, and land allocations. Project planning implements the broad programmatic direction, by accomplishing procedural requirements and designing activities that tailor substantive management direction to the unique conditions and circumstances of a particular site.

Conservation measures address a variety of programs and activities that occur on federal lands, or are authorized or funded by federal agencies.

11. **Effects of Winter Recreation on Lynx.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 49-63. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Because of the secretive nature of lynx and their habit of using deep-forest habitats, few ecological studies of lynx exist, let alone research on the effects of winter recreation. However, the paucity of data should not be construed as evidence that winter recreation has no adverse effects on this species.

Snowmobiling may be particularly adverse to lynx because: 1) this activity occurs when animals are frequently in poor condition due to the stresses of winter; 2) this activity may be dispersed on the landscape (i.e., not confined to roads) on national forest lands outside of wilderness areas; 3) it may occur at night when lynx are usually active; 4) it is frequently accompanied by human disturbance and habitat loss associated with recreational infrastructure; and 5) this activity may alter the density and distribution of snowshoe hares, a favored prey item.

Disturbance, however, does not necessarily lead to a continued reduction in habitat effectiveness for lynx.

Surprisingly, disturbance by people may have a greater negative effect than motorized vehicles on established roadways because mammals habituate more quickly to mechanical noise than to noise from humans. Laughing and yelling can arouse responses of mammals at greater distances than snowmobile noise (Bowles 1995).

Management Guidelines: Snowmobile traffic may reduce the effectiveness of lynx habitats that are peripheral to groomed snowmobile routes. Lynx and hares that use habitats in the vicinity of roads may be adversely stressed by disturbance. Night use of roads may be more detrimental than day use because lynx are nocturnal and crepuscular. However, lynx may show some habituation to snowmobile activity where it is temporally and spatially consistent. Restrictions on quantity and timing of snowmobile travel could reduce adverse effects on lynx. Snowmobiles are frequently used in the backcountry at high elevations, often within or near lynx habitat. Because this activity is highly obtrusive and usually dispersed on the landscape, it has a strong potential to displace lynx from their winter haunts, increase stress levels, and reduce the fitness and viability of lynx populations (Cole and Landres 1995).

Moose

1. **Effects of Winter Recreation on Northern Ungulates with Focus on Moose and Snowmobiles.** Harris, G., Nielson, RM, Rinaldi, T. and Lohuis, T. (2013) European Journal of Wildlife Research http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1441&context=usfwspubs

Abstract: Winter recreation can displace ungulates to poor habitats, which may raise their energy expenditure and lower individual survivorship, causing population declines. Winter recreation could be benign, however, if animals habituate. Moreover, recreation creates trails. Traveling on them could reduce energy expenditure, thereby increasing ungulate survivorship and generating population benefits. Balancing recreation use with wildlife stewardship requires identifying when these effects occur. This task would be simpler if guidelines existed to inform assessments. We developed and tested such guidelines using two approaches. First, we synthesized literature describing the effects of winter recreation – motorized and nonmotorized – on northern ungulates. This synthesis enabled formulating six guidelines, while exposing two requiring further attention (ungulate habituation and displacement). Second, we tested these two guidelines and evaluated the others by quantifying the behavioral responses of moose to snowmobiles, in two areas of south-central Alaska, differing by snowmobile predictability. For each location, we modeled moose preferences during the snowmobile period using different combinations of eight variables – s static (elevation and slope), biotic (habitat and cover), and anthropogenic (distance to roads, railroads, snowmobile trails, and trail density). We identified the model with the most support and used it to estimate parameter coefficients for pre- and post-recreation periods. Changes in coefficients between periods indicated snowmobile effects on moose. Overall, we produced and evaluated six guidelines describing when winter recreation is potentially detrimental to ungulates as follows: (1) when unpredictable, (2) spanning large areas, (3) long in duration, (4) large spatial footprint, (5) nonmotorized, and (6) when animals are displaced to poor quality habitats.

2. **Effects of Winter Recreation on Moose.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 73-86. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Individual animals may be affected if a flight response is initiated by contact with vehicles. Moose may use the groomed surface as a travel route and invite collisions with oversnow vehicles. If human activities are predictable, moose may become habituated.

Management Guidelines: Where human use does occur in moose winter range, regulate activities to make them as predictable as possible. This can be accomplished by restricting them spatially and temporally. For example, restrict skiing or snowmobiling to designated paths and to daylight hours.

3. **Reaction of Moose to Snowmobile Traffic in the Greys River Valley, Wyoming.** Colescott, J.H. & Gillingham, M.P. (1998) ALCES Vol. 34(2): 329-338.

Abstract: Understanding how human activities influence wildlife populations is increasingly important as recreational demands on critical habitat increase. We studied the effects of snowmobile traffic on wintering moose (*Alces alces*) in the Greys River drainage, Wyoming from January through February, 1994. Based on 736 moose-hours of direct observations on large willow flats, moose (6 females, 8 males, and 3 juveniles) were active 41.7% and inactive 58.3% of the observation time. Bedding activity lasted on average 118.7 minutes (range: 1 – 144 minutes) and feeding averaged 32.1 minutes (range: 1 – 274 minutes). Standing, walking, and running occurred only for short periods of time, less than 7 minutes on average. Moose bedding within 300 meters and feeding within 150 meters of passing snowmachines altered their response to the disturbance. This response was more pronounced when moose were within 150 meters of the disturbance. The frequency of snowmobile traffic did not seemingly affect the average percent of moose active, or the number of moose present in the study areas. Moose appeared to move away from the active snowmobile trail as the day progressed. Consequently, snowmobile traffic, although it did not appear to alter moose activity significantly, did influence the behavior of moose positioned within 300 meters of a trail and did displace moose to less favorable habitats.

4. **Influence of Nordic skiing on distribution of moose and elk in Elk Island National Park, Alberta.** Ferguson. M.A.D., & Langvatn, R. (1985) Canadian Field Naturalist, 96: 69-78.

Abstract: Effects of cross-country skiing on distribution of Moose and Elk during winter were studied on Elk Island National Park, Alberta. Aerial observations and track and pellet-group counts provided indices to distribution that could be related to trail location and/or use. Cross-country skiing influenced the general over winter distribution of Moose but not of Elk. Both species, however, tended to move away from areas near heavily-used trails during the ski season (January-March). Day to day movements away from trails occurred after the onset of skiing, but such displacement did not increase with the passage of additional skiers.

5. **Snowmobilers, Their Experience and Habitat Preferences, and the Implications for Wintering Moose.** Jonker, P.M. Jr. (1984) University of Calgary Master's Thesis.

Abstract: The compatibility of habitat requirements of snowmobilers and of moose was assessed. 306 snowmobile users were interviewed from January to April, 1982, at McLean Creek Snowmobiling Area, Alberta. Physical, psychological, and socio-economic dimensions of the sample were derived and described, as well as local behavioral characteristics, and their preferences for vegetation type, density, slope angle, snow depth, and snow type.

Comparison of the snowmobiler's requirements with those of moose indicates clear conflict of demand over "short deciduous" vegetation stands, and conifer and deciduous stands having densities of 100 – 1000 stems per hectare; such stands offer at the same time good snowmobiling and the bulk of moose browse. Moderate potential conflict exists over "roads and trails," moderate slopes, tree stands having densities of 1001 – 2000 stems per hectare, and powder snow on a firm base. A clear conflict over these is expected to be initiated actually only in the presence of deep snow accumulations, such as do not occur at McLean Creek Area. Minimum demand conflict exists for most parameters measured, including non-vegetated terrain, dense stands of trees, thin powder snow, deep powder snow, landform types, flat topography, and steep slopes.

Rabbits

1. **Effect of snowmobile noise and deer and rabbits in their natural habitat**. Bollinger, J. (1974)

Abstract: The behavioral patterns of deer and rabbits before, during, and after extensive snowmobile activities were studied. The data gathered was used to assess the noise wildlife levels associated with various behavior patterns, and to assess the noise levels generated by different snowmobile uses on various types of terrain. Additional objectives were to determine the effects snowmobile noise and activity had on the home range of the deer and rabbits and their seasonal movements; to determine the reactions these animals had to men in the area not using snowmobiles but equipped with skis and snowshoes; and to determine if there was a difference in predator behavior in areas where snowmobiles were used versus those where no vehicles were operated. The research team was unable to detect a severe or negative animal reaction to noise generated by vehicles. Conclusions of the study indicate that the deer and rabbits were not forced to move out of their normal home ranges, nor did they seek shelter or remain stationary with fright while snowmobiles were being operated. The only negative effect determined was that the animals did increase their movement during extensive vehicle use periods. Researchers were unable to determine whether it was the noise, physical presence or both that caused the disturbance.

Reindeer

1. **Behavior Responses of Wild Reindeer to Direct Provocation by a Snowmobile or Skier.** Reimers, E., Eftesddl, S., & Colman, J.E. (2003) The Journal of Wildlife Management, Vol. 67, No. 4, pp. 747-754.

Abstract: To better understand the effect of winter tourism and public recreation on wild mountain reindeer *(Rang* tarandus tarandus),* we compared reindeer response distances after direct provocations by skiers and snowmobiles during three winters in Setesdal-Ryfylke, southern Norway. Reindeer being provoked by a snowmobile discovered the observer at longer distances than reindeer being provoked by a skier *(370* [skier] vs. *534* [snowmobile] m; *P = 0.002),* while total flight *(756* vs. *570* m; *P= 0.037)* and total distance moved *(970* vs. *660* m; *P= 0.008)* by reindeer were shorter for snowmobile than skier provocation. The fright *(328* [skier] vs. *328* [snowmobile] m), flight (281 vs. *264* m), and escape *(543* vs. *486* m) distances due to skier or snowmobile provocation were not different *(P> 0.05).*For pooled data, fright distances of reindeer were affected by *two* other independent variables. Fright distance was longer when the animals were provoked from below rather than from above *(P= 0.046),* while their escape distances were longer when the animals were lying rather than when grazing prior to being provoked *(P< 0.05).* Based on maximum and minimum distance moved for all provocations pooled, daily estimated energy expenditure of reindeer increased between *31* and *590* **kJ,** representing *0.2* and 2.9% of their estimated total daily energy expenditure. Overall, provocations by skiers or snowmobiles revealed similar behavioral responses. An estimated maximum rate of *3* daily encounters between reindeer and skiers or snowmobiles during winter vacation and Easter would result in moderate energy costs that should be easily compensated for and thus have no demographic consequences. Increasing snowmobile use will, however, significantly expand the area where humans are in contact with reindeer during winter and spring, a period of negative energy balance for reindeer.

Sheep / Mountain (Bighorn)

1. **Effects of Winter Recreation on Bighorn Sheep.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 5-9. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Bighorns may abandon high quality winter range that is heavily used by humans, or they may limit their use to a small area near escape terrain.

Management Guidelines: Skiing, snowmobiling, mountaineering, and snowshoeing will most likely only affect bighorn sheep wintering at higher elevations. The encounters between these recreationists and the bighorns may be infrequent enough that there would be little or no impact to the animals. However, if use increases at these higher elevation winter ranges, managers need to monitor the situation in order to prevent the loss of bighorn sheep on isolated winter ranges; human activities should be limited to roads or trails to minimize disturbance to bighorn sheep.

2. **How off-highway vehicles affect mountain sheep.** Laing, M. E. (1992) National Off-Highway Vehicle Conservation Council**:** 1-2 http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0014-how%20OHV%20affect%20mt.%20sheep.pdf

Abstract: A NOHVCC Fact Sheet summarizing one study in Alberta of sheep response. Humans on foot, humans with dogs, and humans approaching from above (over a ridge) proved to be more disturbing than motor vehicle traffic.

3. **Cardiac and behavioral responses of mountain sheep to human disturbance**. Macarthur, R. A., Geist, V., & Johnston, R. H. (1982). Journal of Wildlife Management., 46(2), 351-358. http://nohvcclibrary.forestry.uga.edu/SCANNED%20FILES/W-0039pdf.pdf

Abstract: Telemetered heart rates and behavioral responses of mountain sheep were recorded in response to human disturbance in the Sheep River Wildlife Sanctuary in S.W. Alberta. Cardiac and behavioral responses of sheep to an approaching human were greatest when the person was accompanied by a dog or approached sheep from over a ridge. Because the road is the focal point of human activity in the sanctuary, few responses were observed in reaction to traffic or approach by humans walking directly from a parked vehicle. Similarly, there were no responses to helicopters or fixed winged aircraft at distances >400m from the sheep. This shows that wildlife respond to the predictability of humans.

4. **Observations on the decline of the Rock Creek, Montana, population of bighorn sheep.** Berwick, S. H. (1968). University of Montana, Missoula: 245pp.

Abstract: Among factors that may be responsible for an observed decline in a Montana bighorn sheep population are human disturbance and harassment of sheep. Snowmobile use of an important segment of sheep winter range is increasing. It is suggested that harassment may be debilitating to winter-stressed animals.

Subnivean (under-the-snow) mammals

1. **Winter Recreation Effects on the Subnivean Environment of Five Sierra Nevada Meadows.** Wildlife Resource Consultants, (2004) U.S. Forest Service, Lake Tahoe Basin Management Unit.

Study Introduction: Adaptations to snowpack are an important component of the ecology of small mammals in temperate climates. Some small mammals, such as chipmunks (*Tamias spp*), hibernate and have limited interaction with the snowpack environment. However, shrews (*Sorex spp*) and voles (*Microtus spp*) stay active throughout the winter, and much of their activity occurs in the subnivean space under the snowpack. Other species undergo bouts of torpor between activity (Family: Muridae; deer mouse *Peromyscus maniculatus*). The habitat of species active in the winter includes mesic and dry meadows throughout the Sierra Nevada.

These subnivean mammals are dependent on the subnivean space between the basal layer of snow and the ground for shelter, foraging, and travel. Past research suggests that subnivean space may be formed in one of two ways: mechanically or thermally (Dr. William Pruitt, personal communication). The relative importance of each of these mechanisms in forming biologically useful subnivean space varies by region and type of snow. Subnivean space forms mechanically when the weight of the snowpack is supported by vegetation, woody debris, or complex rocky environments.

Extensive subnivean space may be formed thermally in environments with a temperature gradient between the bottom and top of the snowpack. The snowpack undergoes changes in vertical structure through a process called constructive or temperature gradient metamorphism (Marchand 1991). As water vapor migrates up from warmer to colder regions of the snow, depth hoar forms just above the ground at the base of the snowpack. Open space develops due to loss of water and snowpack during coalescence into larger crystals and transfer of water vapor up through the snowpack. Depth hoar is brittle, loosely arranged crystals that create space in the subnivean environment and facilitate travel by small mammals that readily move through the fragile crystals. In some areas, the basal layer of depth hoar may be 10 to 20 cm thick with individual crystals as large as 10 mm across (Pruitt 1984).

Depth hoar commonly forms and is most well-developed in cold, continental type regions where temperature throughout the snowpack varies significantly. It is documented in three of six snow classes: tundra, taiga, and alpine. These classes were delineated by Sturm et al. (1995) who developed a seasonal snow cover classification based on three climatic variables (temperature, wind speed, and snowfall). Depth hoar is rare to nonexistent in snow classified as maritime, which also tends to be more isothermal.

Study Need – Concern about the effects of winter recreation on wildlife, particularly snowmobiling and grooming of snowmobile and cross country ski trails, has grown as these sports have become more popular. Impacts from snowmobile use have received the most attention and include concern that the compaction of snow destroys the subnivean environment, which reduces temperatures leading to increased metabolic rates, restricts movement, suffocates animals, and increases winter mortality.

Most of typically listed potential impacts are not an issue in the Tahoe National Forest because the large mammal species for which such effects have been documented do not inhabit this area (e.g., elk, bison, white-tailed deer, lynx), and wildlife use naturally decreases because many animals hibernate (e.g., black bears) or migrate (e.g., mule deer) to lower elevations where snowmobile use does not occur. However, snowmobiles could potentially impact subnivean animals through compaction of the subnivean space. Any adverse effects to subnivean animals could indirectly affect the prey base for many Forest Service sensitive species, including the northern goshawk, and pine marten. A reduction in the number of prey could cause a decline in the diversity or numbers of wildlife occurring in an affected area, and could preclude the establishment of a sensitive species later in time as additional acreage of suitable habitat develops in response to Forest Service management direction.

Studies cited as the basis for impacts to the subnivean environment and subnivean animals were generally conducted in locations with continental snowpacks (e.g., alpine) where depth hoar develops. When these studies are cited in environmental documents for agency management decisions (USDA 1999a, 1999b) and in public comments and lawsuits (Biodiversity Legal Foundation. 1995; Bluewater Network. 1999), no caveats are applied regarding the utility of the results to different snowpack classes. No studies are known to have investigated the distribution of subnivean space or the effects of winter recreation on subnivean space in maritime snowpack conditions, such as those found in the Sierra Nevada Mountains. This study was designed to examine the distribution of subnivean space in Sierra meadows, how it is formed, and the impacts of winter recreation on snowpack characteristics and subnivean space.

<u>Results:</u> Sixty-five snow pits were examined for subnivean space, density characteristics, temperature, vegetation type, and the presence of small mammal sign. A summary of the major characteristics of these pits is given in Table 2 in Appendix A of the study.

Subnivean Space – A total of 25,037 cm of snow pit perimeter was examined for subnivean space. Among all 65 pits, a total of 15.6% (3,991 cm) was classified as subnivean space. The percent of subnivean space per snow pit varied from 0 to 70% (Table 2, Appendix A). The subnivean space did not contain depth hoar. The basal layer of snow above the subnivean space was characterized by either wet snow consisting of rounded crystals or a layer of ice. The ground below the ice layer was typically moist, but was never frozen. Some snow pits dug later in the season (i.e., March and April) intersected pooled water. In some cases, the water was extensive enough that the perimeter of the pit could not be sampled and a new pit had to be dug. Where subnivean space was absent, the basal layer of snow rested directly on the ground.

Pooled data for all sites were analyzed by recreational use category. One pit (Number 14; Page Meadows; January 25) intentionally excavated over a large down log (estimate > 18" dbh) was excluded from this analysis because similar woody debris sites were not replicated in all recreational use categories. The pit's total perimeter was 360 cm of which 237 cm (65.8%) were subnivean space. The subnivean space had a smooth, glazed roof with an average vertical height of 6.4 cm.

The "No Use" category had substantially more subnivean space than all other use categories, with an average of 31.4% of the total pit perimeter averaged over 18 pits. This was nearly three times the percent of the pit perimeter occupied by subnivean space for any of the other use categories. Pits classified under one of the two skiing uses or the dispersed over-snow vehicle use were very similar, with an average of about 10.5% of the perimeter occupied by subnivean space. Pits classified as concentrated over-snow vehicle use had the least subnivean space, an average of 6.0% (n=7).

The vertical height of the subnivean space ranged from 1 cm, the minimum height chosen to represent subnivean space in this study, to 6.9 cm. The greatest vertical height was associated with four factors: (1) riparian shrubs, such as willows (e.g., pit 16); (2) large diameter downed wood (e.g., pit 14); (3) vole runways depressed in the ground (often several centimeters) that traversed under the perimeter of the snow wall (e.g., pit 23); and (4) a dense mat of grasses, sedges, and forbs (e.g., pits 19-34). Snow pits dug at Trout Creek Meadow had a relatively large vertical height due to both rodent burrows and the dense mat of herbaceous vegetation.

The presence of subnivean space was highly variable by site. The total percent of subnivean space for all samples from a given study site varied by location. Snow pits dug at Trout Creek had the greatest percentage of subnivean space in the perimeter while those dug at Mount Rose Meadow had the least. Alternatively, snow pits at higher elevations had the least amount of subnivean space, while those at the lowest elevation had the greatest amount.

Table 3: Pooled Percent of Subnivean Space for All Survey Locations for Each Type of Use

Use	Number of Pits	Total Perimeter (cm)	Total Subnivean Space (cm)	Percent Subnivean Space
Concentrated Cross-country ski	7	2,362	259	10.9%
Dispersed Cross-Country Ski	15	5,885	619	10.5%
Concentrated Snowmobile	7	2,428	140	6.0%
Dispersed	17	6,984	745	10.6%

Snowmobile				
None	18	7,373	2,439	31.4%
Total	64	25,037	3,991	15.2%

Because pits were generally constructed in areas representing a range of recreational uses at each site, other factors than recreational use influence the presence of subniveal space. For example, the amount of subniveal space in Page Meadows pits was substantially lower across all recreational use categories than at any other site. Compared to other sites, Page Meadows had deep snow and less dense vegetation. Thus, while this analysis suggests that recreational uses had a negative effect on the presence of subnivean space, examination of the entire data set showed that other factors are also influential. The type of vegetation and snow depth appear to play a major role in either the development or maintenance of subnivean space.

Influence of Vegetation: The average percent of subnivean space in the pit perimeter was calculated for all pits pooled by vegetation community type, as well as the average height of subnivean space. Pits dug in riparian shrub communities had the highest percent of the pit perimeter occupied by subnivean space, and the highest average height of subnivean space. Silver sage and wet meadow communities had similar subnivean characteristics, and while both were lower in subnivean space occurrence and height than the riparian shrub community both were also substantially higher than the dry meadow vegetation community.

Vegetation structure appears to be an important factor in creating subnivean space. Subnivean space was high in the vegetation communities with woody shrubs, likely due to the influence of stems that are less compressible than in herbaceous vegetation communities. However, subnivean mammal use was not noted in pits dug in the riparian shrub or silver sage community types. Absence of mammal sign may have been an artifact of pit construction, as the pits with woody shrubs were extremely difficult to construct and sign may have been obliterated during construction. Because no mammal use was noted in the shrub communities, and because the sample size in these communities was small and was not proportionately distributed among recreational use categories, the shrub communities were excluded from the following analysis of recreational effects.

Wet meadows, with their additional herbaceous density and height, may provide more subnivean space compared to dry meadows. For example, the vegetation in the snow pits at Trout Creek consisted of a dense mat of sedges, grasses, and forbs that formed the subnivean space between the basal layer of snow and the ground. The mats were loosely packed between the snow and the ground, which presumably allowed for easy movement by subnivean mammals and multiple signs of activity were common at this site. Trout Creek and Perazzo Meadows contained the greatest proportion of wet meadow and had the first and second largest amounts of subnivean space, respectively.

Dry meadows typically consisted of patches of low herbaceous vegetation (<10 cm height) interspersed among larger areas of bare ground. Bare ground was sometimes characterized by sparse, flattened remains of decomposed vegetation. Decomposition appeared to have already occurred as a cover of grasses was observed at snow pit locations (e.g., Page Meadows, Mount Rose Meadow) prior to the snow study.

Influence of Snow Depth: The average percent of subnivean space in the pit perimeter was calculated for all pits pooled by snow depth class, as well as the average height of subnivean space. Pits dug in shallower snow had substantially more subnivean space than pits dug in deeper snow, and the height of the space was greater in the shallower pits. This suggests that the depth of snow, which is affected by elevation, strongly influences the development and maintenance of subnivean space. However, there was also a correlation between snow depth and vegetation communities, as most of the pits constructed in low snow depths were also constructed in wet meadows.

Influence of Recreational Use: Except for concentrated cross country skiing, all classes of recreational use, including no use, were fairly well distributed among dry meadow. Pits dug in wet meadow vegetation communities were also well distributed among recreational uses, but there were more pits dug in areas categorized as no use. Also, more pits dug in shallow snow were in the no use recreational category than in other recreational use categories. Given that low snow depth and wet meadow vegetation are correlated with high subnivean space, some of the difference in the amount of subnivean space development between recreational use categories in the following analyses is likely due to these factors.

Excluding pits dug in the shrub vegetation community types, average percent perimeter occupied by subnivean space was calculated for all sites by recreational use, along with the average height of subnivean space. The percent of subnivean space in the pit perimeter was highest in the no use category, followed by concentrated cross country skiing. Both had more subnivean space than the other three uses. Standard deviations of all averages by category overlap due to high variability between pits within categories. None of the differences between use categories would be statistically significant.

Somewhat similar trends were seen in average height of the subnivean space. Concentrated cross country skiing had the highest average height, closely followed by no use. Both over-snow categories were only slightly lower, while cross country skiing was substantially lower.

These data suggest that recreational use has a negative effect on the development and maintenance of subnivean space. It is important to note, however, that high variability between pits and the presence of other factors significant conclusions within this study.

Snow Density – A scatter-plot of all density samples in all pits was constructed. Samples taken in pits constructed in no use areas tend to cluster toward lower density, suggesting that recreational use tends to increase snow compaction. Profiles of snow density by depth were also plotted for each pit. To eliminate the effects of snow depth or season, single plots contain profiles only for one meadow on one day. These plots generally show consistent increases in density with depth among all uses. On plots comparing oversnow vehicle density to no use, over-snow vehicle profiles tend to show higher density (e.g., Perazzo Meadows 17 and 25-Jan-04, Molly Meadow 8-Mar-04). There was no detectable difference between no use profiles and profiles for either cross country skiing category.

Snow Temperature – Most of the pits constructed were relatively isothermal. While temperatures in the pit walls varied between -7 and 5 degrees C over the course of the study, more than 90% of the temperature measurements were between -3 and 2 degrees C regardless of depth. There is no detectable relationship in the scatter-plot between recreational use and temperature.

Profiles of temperature by depth were also plotted for each pit. To eliminate the effects of snow depth or season, single plots contain profiles only for one meadow on one day. These plots generally reinforce the conclusions that the pits tended to be isothermal, but there is no consistent relationship between recreational use and temperature.

Ram Hardness Profiles: Ram hardness depth profiles were compared to directly measured density at two pit locations. Ram profiles generally agreed with directly measured profiles, and contain more detail. However, there was no evidence that the ram penetrometers can accurately detect the presence of subnivean space.

STUDY SUMMARY DISCUSSION

Implications for Subnivean Animals: This study's results suggest that snowmobiles and cross country skiing may affect the amount of subnivean space, but both snow depth and vegetation are also strong influences. While recreational use did appear to affect snowpack density, it could not cause the same adverse effects reported in other study locations such as destruction of depth hoar, since this snow type did not occur in the study areas. The effects of winter recreation on subnivean space have been best documented in continental climates; it appears that different effects are likely to occur in the maritime climate of the Sierra Nevada where the conditions that lead to the formation of depth hoar do not exist. (This phenomenon was already known to snow scientists (Sturm et al. 1995)). Instead, the distribution of subnivean space correlates with snow depth, vegetation type, and woody debris.

In environments with fluctuating temperatures, the moisture gradient may move down from the snow surface as well as moving up from the bottom (Dr. Pruit, William, personal communication). In such cases, the snowpack rests directly on the ground as it does in the study area's portion of the Sierra Nevada Mountain Range. Pruit observed (1984) that only one species of vole was found on the Strait of Belle Isle in Newfoundland. He postulated that the lack of depth hoar in the maritime climate was an important factor governing the depauperate small mammal fauna. However, in the Sierra Nevada study sites, at least four species of subnivean mammals are known to occur in the study's meadows (Manley and Schlesinger 2001; Unpublished data Trout Creek Restoration Monitoring).

The lack of depth hoar in the subnivean space presents an interesting dilemma for understanding the winter ecology of subnivean animals in Sierra Nevada meadows. The question arises, how do the subnivean animals that occupy the meadows in the summer adapt to a maritime snow pack that rests primarily on the ground with very little subnivean space?

In the Ural Mountains of Russia, subnivean mammals were found to migrate before winter from meadows to talus slopes (Bolshakov 1984). The Ural Mountains have a dense maritime snowpack, which probably produces little thermally created subnivean space in meadow areas. Talus slopes, however, provide subnivean space due to support of the snowpack by larger rocks and boulders.
Perhaps subnivean animals that occupy dry meadows in the Sierra Nevada move to and concentrate in mechanically formed subnivean space located in dense herbaceous vegetation, woody shrubs, or around large down logs. If so, then winter recreationists would be unlikely to affect the early season formation of subnivean space over woody shrubs or large woody debris. Until there is a deep snow cover, recreationists tend to avoid woody shrubs as they are difficult to move through and logs can be difficult to cross because of breaking into the subniveal space. Later in the season as snow depth increases, recreational use of these sites probably has a minimal effect due to the snow depth (as seen in pits 14-18).

Not all subnivean animals are restricted to the subnivean environment. In the tundra of Alaska, temporarily enlarged winter claws enable *Dicrostonyx* lemmings to dig tunnels up through harder layers of snow (Pruitt 1984). However, no burrows constructed by voles or shrews were observed in the basal or upper layers of snow within the pits. Burrows dug by voles descended into the soil.

Niveal (in the snow) burrows constructed by gophers (*Thomomys spp*) were observed at Perazzo Meadows, Page Meadows, and Mount Rose Meadows. The tunnels were observed at a variety of heights above the ground (5-12 cm) in the wall of the study pits. Gophers have long claws, which facilitate their digging in hard snow. When excavated, many of the tunnels were extensive.

The material inside the tunnels consisted of a loose or solid mix of dirt, dead vegetation, and occasionally gopher scat. A careful search of the material from multiple tunnels did not reveal any vole scat. Shrew scat would most likely be too indistinct to detect in such material. Subniveal space was observed beneath the dirt core of some niveal burrows, especially as they descended down toward the soil surface. It is unknown whether voles or shrews used this space or used the gophers' fossorial burrows that connected to the niveal tunnels.

Recreation use did not appear to affect niveal burrows as they were noted in areas with concentrated snowmobile use in Mount Rose. Subsequent to this study, on April 27, 2004, a niveal gopher burrow was observed at Perazzo Meadow traversing under a groomed snowmobile trail located on a hard surface road.

The actions of the subniveal animals themselves appear to create subnivean space. Vole runways depressed into the ground sometimes contributed several centimeters to the measured height of the subnivean space. It was unclear whether repeated use contributed to the runways' depression or whether they were excavated into the ground.

The configuration of the measured subnivean space was disjunct and highly variable. Whether subnivean animals use the available spaces and how they move from one area of open space to another is unknown. Grass vole nests observed on the surface of Mount Rose meadow following snowmelt suggests that voles do occupy the space between the basal snow layer and ground. Although a network of depressed runways could facilitate travel under the snow, it seems unlikely that voles could forage effectively where the snowpack rests directly on the soil surface. These findings suggest the importance of food hoarding for winter survival of active subnivean mammals such as shrews and voles (Vander Wall 1990).

Recommendations for Future Studies: This study was specifically designed to examine the effects of established winter recreation use as it actually occurs over time. However, relying on "natural" use patterns created several problems, including the lack of control pits at Mount Rose meadow. Because it was unknown exactly where the recreational use would occur for each site, pit locations could not be delineated prior to snowfall. Therefore, vegetation community type could not be predicted and could only be determined once a pit was dug. Even in study areas well known to the primary investigator, problems were still encountered. For example, several late season (March) pits dug at Page Meadows were placed over pools of water even though efforts were made to avoid them

Digging pits was labor and time intensive. The number of pits that could be dug each day depended on snow depth and on weather. Fewer pits were dug in deep snow and in harsh weather conditions. Ideally, the ram penetrometer could be used to characterize the snowpack density, thus precluding the need to dig snow pits. However, the ram was ineffective at detecting subnivean space in the maritime snow conditions. The ram could not be used to detect mechanically formed space at the base of the snowpack in riparian shrub habitat as its downward progress was blocked by a network of unseen limbs.

If additional work is conducted, consideration should be given to excavating linear trenches, which might allow sampling in the same pit for both use and non-use. Conducting the snow pit survey from January through April might have confounded the investigation by increasing the number of variables. Future research should consider increasing the number of pits dug to produce statistical significance and limiting seasonal variability by concentrating pit digging in one month.

It was not possible to perform a multifactorial analysis in this study because the importance of snow depth and vegetation type on the formation of subnivean space was not understood. Therefore, any future study must identify vegetation type prior to snowfall. The best method to locate pits in known vegetation types would require a detailed vegetation map with significant areas of each vegetation type so that pits could be accurately sited. However, staking sites before snow cover is impractical because of the labor required to maintain the stakes as snow depth increases and because people could move the stakes.

Percent of the pit perimeter occupied by subnivean space appears to be a useful metric in evaluating the effects of recreational use. However, data from this study show that the variable is highly skewed and non-parametric tests may be required. It should be possible to design a multifactorial study that would evaluate the statistical significance of snow depth, vegetation type, and recreational use. A controlled study with recreational use simulated in known environments is likely to provide the best results. Natural recreation use patterns do not allow for sufficient comparison of recreation type, vegetation type, and snow depths. However, the time and expense required would be greater than this study, and excluding regular recreationists from a site to maintain a control location could be problematical.

Potential future research should investigate the winter use of dry meadow habitat by subnivean animals. If subnivean animals migrate out of these sites, then winter recreation use is likely to have a reduced or no effect on these animals.

Recommendations for Management: Vegetation community types should be considered in managing winter recreation use in the Sierra Nevada. This study strongly suggests that wet meadows at low elevations with low snow depth probably have the most subnivean space. This study's findings were not as conclusive regarding the effects of recreational use on subnivean space. But there is some suggestion that winter recreation may impact subnivean space at low elevations. Winter recreation probably has the greatest effect at low snow depths. Further research is needed to produce data that can be tested for statistical significance, with controlled variables, and even distribution of snow pits among the recreational use categories, snow depth, and vegetation types.

2. **Effects of Winter Recreation on Subnivean Fauna.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 97-99. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Most research relating to the impacts of winter recreation on subnivean fauna has concerned the effects of snow compaction due to snowmobiles on the animals. One of the potential impacts of snow compaction is alteration of the snow microclimate, especially the physical and thermal aspects (Corbet 1970). Some possible changes in snow conditions resulting from snow compaction include a decrease in subnivean air space, a change in temperature, and accumulation of toxix air under the snow (Jarvinen and Schmid 1971, Schmid 1971a and b).

According to Halfpenny and Ozanne (1989), skiers may do more damage to the snowpack than snowmobilers because narrow skis cut deeper into the snowpack and because skis have a greater footload (amount of weight per surface area) in comparison to a snowmobile track. For both ski tracks and snowmobile tracks, multiple passes over the same track will have more impact than a single pass.

Management Guidelines: The lack of information about impacts to subnivean mammals from winter use makes it difficult to draw conclusions…the only management guideline is to encourage more research on the subject.

3. **Ecological impacts of off-road recreation vehicles: Outdoor recreation research applying the results:** Brander, R. B. (1974)

Abstract: This paper focuses on the environmental impacts of snowmobiles. It is not a scientific study; instead the author infers some effects from existing literature on the structure and mechanics of snow and the significance of snow to small mammals and their predators. The insulation that snow provides is very important to small mammals which spend most of the winter at the ground and snow interface. Mechanical compaction reduces snow depth and increases thermal conductivity and snow densities by destroying air spaces. This can result in loss of habitat and in some cases mortality in some small mammal populations. The decrease in small populations of small mammals can in turn negatively affect their predators, and on up the food chain. More scientific information is needed. Because snowmobiles accelerate the rate of environmental degradation compared to hikers, existing information should be used in making management decisions. One suggestion is to restrict traffic to a few trails and roads rather than allowing free access to fields, etc.

4. **Snowmobile activity, subnivean microclimate and winter mortality of small animals**. Schmid, W. D. (1972) Bulletin of Ecological Society of America, 53(2), 37.

Abstract: Mechanical compaction of snowfields by snowmobiles alters the mild subnivean microclimate and promotes densification of snow. The stress of winter temperatures may increase for organisms that live within or beneath these compacted snowfields and the densified snow may be a greater barrier to animal movement in the subnivean space. Experimental manipulation of a snowfield has shown that the winter mortalities of small mammals are markedly increased under snowmobile compaction. We recovered none of the twenty-one marked animals from the experimental plot, whereas eight of eighteen marked specimens were captured at least once on an adjacent control plot.

5. **Snowmobile use and winter mortality of small mammals.** Jarvinen, J. A. & Schmid, W.D. (1971) Paper presented at the M. Chubb, ed. Proceedings of the 1971 Snowmobile and Off the Road Vehicle Research Symposium, East Lansing, MI. Michigan State University.

Abstract: Trapping results in Minnesota showed increased winter mortality of small mammals beneath snowmobile compacted snowfields. It is suggested that compaction inhibits mammal movements beneath snow and subjects subnivean organisms to greater temperature stress. Report states that more information is necessary.

Wolverine

Wolverines are generally classified as a Sensitive Species by the U.S. Fish and Wildlife Service (while not currently listed as Endangered or Threatened at the federal level – several groups continually try to push an elevated designation status through lawsuits and political action; additionally, some individual states do currently classify it as Threatened). They are the focus of several current scientific research efforts. Since its habitat sometimes overlaps with popular winter recreation areas, questions about potential impacts from snowmobiling have emerged over recent years. It is therefore important that snowmobilers and snowmobile trail managers pay close attention to wolverine research to help understand the issues and research findings.

The Wolverine Foundation in particular is associated with numerous research efforts currently in progress and is a good source of information pertaining to recent efforts. Since several research projects are currently on-going, monitor the Foundation's website to track new activities and findings as they are posted at http://wolverinefoundation.org/resources/research-reports/ . A summary of recent Wolverine research reports includes:

Central Idaho Wolverine Winter Recreation Research Project

1. Wolverine –Winter Recreation Research Project: Investigating the Interactions Between Wolverines and Winter Recreation. Final Report. (2017) Heinemeyer, Kimberly S, John R. Squires, Mark Hebblewhite, Julia Smith, Joseph D. Holbrook, and Jeffrey P. Copeland. https://www.snowmobileinfo.org/snowmobile-access-docs/Wolverine-Winter-Recreation-Final-Report-15Dec17.pdf

Executive Summary: Outdoor recreation provides opportunities for people to connect to nature, and is a critical economic driver and part of the cultural fabric of some rural communities. Outdoor recreation is also increasingly recognized to have potentially important impacts on nature and wildlife, and we need to understand these potential effects. In recent years, technological advancements in over-snow equipment including 'powder snowmobiles' and lightweight backcountry ski gear provide opportunity for backcountry enthusiasts to access previously remote landscapes for winter recreation activities. Wolverines may be vulnerable to direct and indirect impacts of recreation during winter, as they remain active through the winter, naturally occur at low densities, have low reproductive rates, and enter reproductive dens within deep snowpack during the winter recreation season. The Rocky Mountains represent the southern extent of wolverine distribution and in this region, they are limited to high elevation habitat, which overlaps the same types of mountainous terrain sought by backcountry winter recreationists.

Over 6 winters (2010–2015) and four study areas, we GPS collared 24 individual wolverines over 39 animal-years to collect >54,000 GPS locations, one of the largest GPS datasets collected on wolverines in the lower 48 states. These wolverines were exposed to a diversity of winter recreation activities across our study areas spanning >1.1 million ha in Idaho, Wyoming and Montana. Simultaneously, we monitored and sampled winter recreation, collecting 5,899 GPS tracks from backcountry winter recreationists representing >198,000 km of recreation activity, in the most intensive and extensive backcountry winter recreation monitoring effort that we know of to date. Backcountry winter recreation information was also collected through trail use counts and aerial-based recreation surveys, and the combination of data allowed us to create maps of backcountry winter recreation portraying the extent and relative intensity of motorized recreation and non-motorized recreation within wolverine home ranges. From locations of 18 wolverines (25 animal-years, >53,000 locations), we modelled habitat selection of male and female wolverines within home ranges using resource selection functions and used remaining wolverine data to validate these models. We characterized the habitat selection responses of wolverines to varying winter recreation patterns, and assessed the potential for indirect habitat loss from avoidance of recreated areas. Replicating this across multiple study areas allowed us to evaluate functional responses of wolverines to differing levels and types of recreation, providing further insights into wolverine responses to winter recreation.

Wolverines exhibited selection for specific habitat characteristics within home ranges, with female selection differed in some important ways from males. Female wolverines, which were represented by both denning and non-denning females in our sample, selected for talus and for snowier and colder habitats when compared to males, and we suggest these may represent denning affiliations similar to those found in other studies. Both males and females selected for drainage bottoms and avoided steep slopes. Both male and female wolverines selected for fir-associated conifer forest, avoided open areas but selected for areas close to forest edges. Unlike females, males were found closer to roads than expected; these roads were primarily unmaintained, snow-covered secondary roads with little human use during winter.

Wolverines maintained multi-year home ranges within landscapes that support relatively intensive levels of winter recreation, suggesting that wolverines tolerate winter recreation at some scales. Individual wolverine exposure to winter recreation varied notably across study areas and animals, a key aspect of our study design. Variation in the spatial extent of motorized recreation ranged from <1% to 51% within home ranges, while non-motorized recreation tended to have smaller footprint areas covering an average of <5%, and ranging from <1% to 9.3% within home ranges. Wolverines responded negatively to increasing intensity of winter recreation, with off-road or dispersed recreation eliciting a stronger response than recreation concentrated on access routes. Indirect habitat loss from winter recreation reduced the quality of 2–28% of available habitat within home ranges. Female wolverines exhibited strong avoidance of off-road motorized recreation and were more vulnerable to higher levels of indirect habitat loss than males who appeared to be less sensitive to disturbance. While non-motorized recreation covered a relatively small proportion of home ranges, these areas were also avoided by male and female wolverines. The avoidance of areas of linear access used by winter recreationists was not as strong as estimated for dispersed recreation and wolverines may be less sensitive to predictable patterns of human use.

The strength of wolverine negative responses to dispersed motorized and non-motorized recreation increased with increasing levels of the recreation within the home range. This functional response of wolverines to recreation intensity suggests that potentially important indirect habitat loss may occur when a notable portion of an animal's home range receives recreation use, as it is exactly those animals exposed to higher levels of recreation that are most strongly displaced from these areas. The functional response also suggests that limited exposure may mute the indirect habitat loss, and some of our animals were exposed to relatively low levels of winter recreation. Our ability to understand wolverine responses to non-motorized recreation is hindered by having few wolverines exposed to higher levels of this recreation type.

Currently, exposure to winter recreation is highly variable within home ranges and across individuals indicating further work is needed to understand population-level effects. We suggest significant habitat degradation to reproductive females during denning season should be of concern within landscapes with higher levels of winter recreation. We speculate that the potential for backcountry winter recreation to affect wolverines may increase under climate change due to reduced snow pack and snow season that may concentrate winter recreationists spatially and temporally in these high elevation habitats during a season when these species face increased energetic stressors and females enter reproductive dens. We recommend that solutions to finding a balanced approach to sustaining the diverse values of these wild landscapes requires creative approaches and collaborations between land managers, stakeholders and wildlife professionals.

2. **Wolverine – Winter Recreation Research Project: Investigating the Interactions between Wolverines and Winter Recreation, 2015 Progress Report.** http://wolverinefoundation.org/wp-content/uploads/2011/02/Idaho-Wolverine-Winter-Recreation-Project-2015-Progress-Report.pdf

Summary: In 2015, we concluded our major field data collection efforts to document wolverine and backcountry winter recreation presence, movements and habitat use.

2015 STUDY AREAS
In 2015, we continued the monitoring of wolverines and winter recreations in key study areas in central Idaho (Payette and Boise National Forests) while focusing our core effort on completing the second full year of data collection in the western Yellowstone region of Idaho, Montana and Wyoming.

The western Yellowstone study areas fall across five federal jurisdictions and three states. The 'Island Park' study area includes the Centennial and Henry Mountains straddling the Idaho-Montana state line on the Caribou-Targhee, Custer-Gallatin and Beaverhead-Deerlodge National Forests (NFs). The Teton study area encompasses the Teton Mountains which fall within the Caribou-Targhee and Bridger-Teton NFs and Grand Teton National Park in Idaho and Wyoming.

WOLVERINE MONITORING
We undertook both live trapping and camera trap-hair collection monitoring in the western Yellowstone study areas and camera trap-hair collections to continue monitoring wolverines in the key study areas in central Idaho.

Salmon Mountains Study Area. In central Idaho, we completed camera and DNA (hair) collection efforts in the Salmon Mountains near McCall on the Payette and Boise National Forests. This winter represented our 6th year of monitoring wolverines in this popular winter recreation area. Our efforts in 2010 and 2011 identified four reproductively active females and four resident males. Based on our subsequent monitoring through 2015, most of these resident animals are no longer present with the exception of F5 who is tentatively identified in photographs near Warm Lake Summit in March 2015 on a station she has routinely visited in prior years. In 2014, we identified and monitored two new wolverines in the Salmon Mountains (one male M12, one female F10) with apparent resident behaviors (e.g., maintain home ranges) with the female establishing a reproductive den in 2014 (Heinemeyer et al. 2014).

We monitored 10 camera-hair snare stations in the Salmon Mountain study area from January-March 2015 for over 700 nights of effort. We did not confirm F10 in the area during 2015 but did have un-identified wolverines visiting the camera-hair snare sites in or near her 2014 home range; these visits did not result in sufficient hair collection for DNA analyses and photos were inconclusive on individual identification. We initially identified and GPS-collared M12 in the Salmon Mountain study area in 2013-14 documenting his movements within the area previously identified as the home ranges of original M2 and M3, and adjacent to the still resident M1. In 2015, we did not detect M1 but found M12 at baited stations within M1, M2 and M3 original home ranges (Figure 2): M12 was found at 9 of our 10 sample sites. If indeed he maintains this vast area as a territory, it would potentially encompass over 1,100 sq. miles rivaling the largest home range we have documented during the study and well exceeding the 'typical' male home range of 500-800 sq. miles.

Based on our camera stations, it appears that the number of wolverines in our Salmon Mountain study area is currently lower than when we initiated the project in 2010. Most notable has been the incremental loss of resident animals without identifying new animals filling these vacant home ranges at densities we initially saw. The probability that we simply did not detect new or resident animals is relatively low given the monitoring effort we invest in the region. Recent analysis suggests that the probability of detecting a wolverine with a baited camera station within its home range over one winter is 86% (Inman et al. 2015). The density of camera – hair snare stations that we deployed and maintained would equate to two or more stations within a typical female home range and more than that within a typical male home range. Additionally, the known resident wolverines readily come into the baited stations and we typically have identified them multiple times over any winter season.

Western Yellowstone Study Areas. In our western Yellowstone study areas (Centennials, Henrys and Tetons), we undertook a mix of live trapping and camera-hair snare monitoring to build on efforts started in 2014.

We deployed 5 camera-hair snare stations in the Centennial Mountains at sites that were live traps in 2014. These camera traps were run for a total of 399 trap nights between early January and late March 2015. In this second year of focused effort, we again did not detect a wolverine in the Centennial Mountains (Table 1). We also attempted to undertake an aerial track survey in the Centennials in March 2015 but weather prohibited completing the effort. The Centennials historically were known to support wolverines. Inman (2007) reported five mortalities (3 female, 2 males) between 2001 and 2005 in or near the Centennial Mountains; his work represents the last confirmed observations of wolverines in the mountain range.

In 2014, 2 wolverines (1 male M14, 1 female F11) were captured in the Henry Mountains along the Montana-Idaho border north of the Centennial Mountains. Genetic analysis indicates that F11 is the mother of M14, likely a kit from 2013. She did not den in 2014 and we re-deployed the trap effort in the Henry Mountains in 2015 with the hope of monitoring her through a denning cycle. We did successfully GPS collar her along with a new male M15. We did not detect M14. The female established a reproductive den in late February and we were able to monitor activity at the den through fixed wing flights. Her collar malfunctioned and we were unable to obtain GPS data. This den represents the ninth reproductive den that we have documented. We visited the den site in August after F11 abandoned it, and recorded habitat and structure information. The den was located on the lower slope of a headwall in an area composed of extremely large talus boulders (Figure 3).

We obtained DNA results that show that M15 is also the son of F11 and the sibling of M14. The father is unknown. The male M15 shows movements characteristic of a resident animal and he maintained a home range covering 619 sq. miles including the Henry Mountains and the southern portion of the Madison Range (Figure 4).

We increased our trapping efforts in 2015 in the Tetons after only capturing a single male (M13) in 2014. We established research teams on both sides of the mountain range and undertook a significant trap effort logging 460 total trap nights over the January-March trapping season using both live traps and camera traps. In addition to live traps (239 trap nights), we set up camera-hair snare traps (221 trap nights) for all or part of the winter season (Table 1). The only wolverine detected was again was M13 (nicknamed "Jed"). From DNA analysis, we know he was initially captured in 2002 in another study in the area when he was identified as a subadult at that time. That original capture makes Jed an estimated 14+ years old – well past prime age and it would be expected that he should have been displaced by a younger, prime-age male if one were present. His relatively small home range of 355 sq. miles may be a reflection of his age (Figure 5). We did not identify any females in the Tetons.

We closed trapping in the Tetons in mid-March due to early spring conditions, in late March in the Centennials and by the end of April in the Henry Mountains, prior to grizzly bear emergence. We made a concerted effort through the end of April to recapture F11 to retrieve the malfunctioned collar before it fell off but we were not successful.

All data from the 6 previous years of wolverine tracking efforts were harmonized and compiled into a single geodatabase with final versions of each animal's points, tracks, and calculated home range for each season in which there was sufficient data for analysis (Table 2).

RECREATION MONITORING

We continued recreation monitoring in both the Henry and the Teton Mountains including handouts of GPS trackers to backcountry recreationists in the 2015 winter field season. A total of 1,239 GPS tracks were collected from January-March: 83 in the Henrys (82 snowmobile tracks, 1 backcountry ski track) and 1,156 in the Tetons (77 snowmobile tracks, 1,067 ski/snowboard tracks, and 12 mixed recreation tracks; Figure 6). The GPS tracks collected in 2015 combined with the nearly 2,000 collected in the previous winter will provide high quality location data that can be used at multiple spatial and temporal scales to evaluate wolverine responses in the Tetons and Henry Mountains, similar to our central Idaho recreation data collected in prior years. Based on our array of remote trail use counters (19 in the Tetons, 3 in the Henrys), these GPS tracks represents a sample from an estimated 32,500 winter backcountry visits: 29,000 backcountry skier and snowmobiler visits in the Teton Mountain study area and more than 3,500 snowmobiler visits in the Henry Mountain study area.

We also completed an aerial recreation survey on March 20, 2015 in the Henry and southern Madison Range Mountains using methods described in Heinemeyer et al. 2011. This survey documents relative winter recreation levels in the northern part of the home range of M15 that encompasses the southern Madison Mountains where we do not have GPS tracking data from recreationists (Figure 4). Like previous aerial surveys in our other study areas, this survey used a standardized sampling approach to provide an independent estimate of the extent and relative intensity of winter recreation. In addition to filling information gaps, these data will be used when working with the GPS track data to identify any inconsistencies or changing use patterns in areas where GPS monitoring efforts have ended.

Over the summer of 2015, we have completed the validating, compiling and harmonizing of these GPS tracks and combined them with data from all previous years to facilitate analysis and modelling. New recreation intensity grids were calculated and the data are attributed to facilitate the creation of more fine-scale analyses such as daily, weekly or weekend vs weekday spatial layers of recreation intensity.

BASE DATA ACQUISITION AND PROCESSING

The capture and tracking of wolverine M15 necessitated a redefinition of the West Yellowstone study area boundary and recompilation of base data layers as he covered regions north into the Madison Range. The new West Yellowstone study area now spans four National Forests (Gallatin, Beaverhead-Deerlodge, Caribou-Targhee, and Bridger-Teton) and two National Parks (Grand Teton and Yellowstone). The Central Idaho study area brings in three additional National Forests (Boise, Payette, and Sawtooth) to the overall study area that spans three states (Idaho, Wyoming and Montana).

Compiling and harmonizing the best available base data between numerous jurisdictions is a significant and ongoing task. In addition to forest and parks data (roads, trails, winter travel routes, area use restrictions), other base data were recalculated to accommodate the expanded study area, including land cover (vegetation cover, type, seral stage, etc.), vegetation characteristics (e.g., NDVI, brightness and greenness indexes), and terrain variables (elevation, slope, aspect, ruggedness). We acquired and mosaicked high-resolution (1-2 m) NAIP imagery for the entire study area to provide a detailed birds-eye view of cover type (circa 2012) and allow for the calculation of high-resolution visual band indices during peak phenology. We are currently generating a solar insolation covariate as a potential predictor of cooler microclimates that may be important to wolverines for denning and habitat selection.

NEXT STEPS

The field data collection for the wolverine-winter recreation project is completed. Our focus is now on the analyzing responses of wolverines to winter recreation, associated report and publication preparation and presentation, assisting agencies and stakeholders in interpreting the results of the research and continuing outreach efforts. The majority of the analysis and reporting is expected to be completed by the end of 2016.

3. **Wolverine – Winter Recreation Research Project: Investigating the Interactions between Wolverines and Winter Recreation, 2014 Progress Report.** http://wolverinefoundation.org/wp-content/uploads/2015/01/Wolverine-Winter-Recreation-Project-2014-Progress-Report-Final.pdf

Executive Summary: We have completed 5 winters of research detailing the interactions between wolverines and winter recreation, including the GPS tracking of both wolverines and winter recreationists in 3 study areas in central Idaho and 2 in the western Yellowstone. We have successfully gathered movement and habitat use information on 17 wolverines and collected over 4,500 tracks of winter recreationists. Heinemeyer and Squires 2013 details past efforts and this report updates that information with data and analyses complete d in 2014. We seek continued support from The Wolverine Foundation as we enter into the final year of field data collection followed by a year of data analyses, reporting and outreach with agencies and stakeholders.

In 2014, we undertook an ambitious wolverine and recreation monitoring effort across 3 study areas and captured and GPS collared 8 wolverines. We collected nearly 2,000 GPS tracks including both backcountry skiers in the Teton Mountains and snowmobilers in the Centennial and Henry Mountain ranges in areas that overlap GPS-collared wolverines and potential wolverine habitats. We compiled these new data with our prior data as we continue data exploration. As we have suggested previously, wolverines appear to tolerate winter recreation in their home ranges, including denning females. Based on our preliminary findings, potential wolverine habitats that have even high levels of winter recreation may support resident wolverines despite the potential human disturbance. However, wolverines exposed to higher levels of winter recreation within their home range may show avoidance of these recreated areas, suggesting potential threshold effects. While these 'high recreation' wolverines may avoid recreated areas, they are still found within locally intense recreation areas 22% of the time but with elevated movement rates. Wolverines that reside in lower recreated landscapes are only found within high-recreated areas 6% of the time but show much higher movement rates than their 'high recreation' cousins. Additionally, we find that denning females show much higher movement rate increases in response to high recreation areas than non-denning females. There appears the potential for some level of habituation but energetic implications are clearly an area of additional research and analyses as we seek to understand these complex interactions.

We require an additional year (winter 2014-15) of field research in the western Yellowstone area and hope to also continue monitoring resident wolverines in our central Idaho study areas. This will be followed by a year (2016) of data analysis, reporting and outreach to agencies and stakeholders.

4. **Wolverine – Winter Recreation Research Project: Investigating the Interactions between Wolverines and Winter Recreation, 2011-2012 Progress Report.** http://wolverinefoundation.org/wp-content/uploads/2011/02/ci_winter_rec_2012update_dec.pdf

Methods and Results To-Date: The goal and objectives of the project require that, from a logistical standpoint, two simultaneous and spatially overlapping projects be conducted: an intensive monitoring of wolverines and an intensive monitoring of winter recreation. This report focuses on presenting information collected during the last 2 winters (2011-2012), and includes 2010 data when helpful; a full reporting of 2010 project information as well as a detailed description of our field methods is available in the 2010 annual report prepared for the project (Heinemeyer et al. 2010).

We have completed 3 winter field seasons, from January 2010 through April 2012. Over the first 2 winters (2010-2011), we implemented both wolverine and recreation monitoring in the Salmon Mountains north and east of McCall, Idaho, referred to as the Payette Nation al Forest (PNF) study area (Figure 1). In 2011, we established a second study area in the southern portion of the Salmon mountains on the Boise National Forest (BNF) near Warm Lake and east of Cascade, Idaho (northern BNF study area). During that second winter, we also completed exploratory field work on the Sawtooth National Forest (SNF) near Stanley, Idaho, which was subsequently selected as the third study area (north SNF study area). During the third winter (2012), we implemented the full wolverine and winter recreation monitoring methods in the northern SNF study area and we continued GPS collar monitoring of key resident animals in the PNF and northern BNF study areas supported by trail use counts and aerial surveys for recreation use. In this third winter, we also implemented exploratory work in the Smoky Mountains north of Fairfield (south SNF study area) and in the Trinity Mountains near Featherville (south BNF study area) as potential new areas for full implementation of the project. This exploratory work included baited camera stations and recreation monitoring.

5. **Project Update: February 2012** http://wolverinefoundation.org/wp-content/uploads/2011/02/ci_winter_rec_2012update_feb.pdf

Summary: Project Expands in 2012: The wolverine-winter recreation project was initiated with aerial surveys across the Payette, Boise and Sawtooth National Forests in 2009 to examine the distribution and potential overlap between winter recreation and wolverine presence. Finding this overlap in several areas, the ground-based research effort began in January 2010 on the Payette National Forest outside of McCall, Idaho.

That first season was truly an experiment. Could we successfully capture and collar wolverines within these recreated landscapes using new GPS collar designs? And, while we felt relatively confident about this, even more uncertain was the reception we might receive from the recreating public as we asked for their help and cooperation. That first season was remarkably successful, due to the hard work of a committed team of field technicians, an open-minded and supportive recreation community and state and federal agency cooperation. We collected excellent information on winter recreation and monitored 6 wolverines that reside in the landscapes used by this public.

In 2011, we returned to McCall for a second year of data collection, and expanded the scope of the study to include the Warm Lake area east of Cascade. We also undertook a preliminary study on the Sawtooth National Forest on wolverine presence and recreation distribution. Again, the second season went better than we dared hope, with wolverines and recreationists critically assisting in our successful data collection efforts. We invite you to read prior Project Updates at www.forestcarnivores.org.

For the project to be able to understand the potential responses of wolverines to recreation, we need to look at a minimum of three landscapes with different and diverse recreation use patterns to monitor wolverines under a variety of conditions. Therefore, the work in our new study areas on the Sawtooth and Boise National Forests are as important as our initial work on the Payette National Forest has been.

Thus, this year – the winter of 2012 – is our most ambitious season yet. We have continued wolverine monitoring and selected winter recreation monitoring across our 2011 study area on the Payette and Boise National Forests. We have initiated a full wolverine and winter recreation study on the Sawtooth National Forest, with crews in Stanley and Fairfield, Idaho. And we are conducting preliminary data collection in the Trinity Mountains of the Boise National Forest, with a crew based in Featherville. So far, the season is going well – we provide some updates for the season here.

Recreationists Are Critical to Success of Research: We have a very ambitious recreation monitoring effort underway this year in the Stanley, Fairfield and Featherville areas where we are asking recreationists to voluntarily and anonymously carry small GPS data loggers. These data loggers provide us with a path the recreationist took that day, time-stamped so that we can match it with where our collared wolverines were at the same time. The data collected will help in various modeling and analyses we hope to complete as part of the study looking at wolverine responses and interactions with recreation of all types.

We cannot overstate how valuable the participation of the recreation community is in these efforts. Because of the cooperation of the recreating community in McCall, we have collected excellent information in that study area on both recreation and wolverines over the last two winters. From this we have found that wolverines in this area are permanently residing even in some of the most highly recreated portions of the study area. This is excellent news, but we still need further information that will allow us to look at reproduction and other indicators of health in the wolverine population – in McCall and in other recreated landscapes.

Again this year, we are really pleased at the interest and willingness to participate that folks have shown when approached by our technicians. This winter is proving to be another example of how team work, collaboration and transparency are a winning combination for all of us invested in ensuring that winter recreation and wolverines both continue to use our beautiful Idaho landscapes.

6. **Project Update: July 2011** http://wolverinefoundation.org/wp-content/uploads/2011/07/ci_winter_rec_2011update.pdf

Summary: Successful Second Winter Season! The Central Idaho Wolverine and Winter Recreation Study undertook its second field season this last winter. In 2011, we repeated work in the same areas north and west of McCall on the Payette National Forest, and also expanded our study area to include through the Warm Lake area east and southeast of Cascade on the Boise National Forest. The focus of our efforts again this year included live-trapping and GPS collaring wolverines to monitor their movements and behaviors and simultaneously asking winter recreationists to carry a GPS data loggers while recreating in the study area. This larger study area certainly meant extra effort, but it was well worth the investment. Over the winter, we monitored 10 wolverines and collected data from hundreds of volunteer winter recreation enthusiasts.

In addition to the intensive efforts undertaken on the Payette and Boise National Forests, we also completed a preliminary study on the Sawtooth National Forest near Stanley, Idaho. In this study, we collected hair for DNA analyses from wolverines visiting potential future trap sites, we monitored trail use using remote trail use counters and we undertook parking lot counts.

Recreation Monitoring: Again this year, we are appreciative and impressed by the generous support of the winter recreationists who volunteered to carry our little orange data loggers. Our crews routinely visited 6 trailhead parking areas throughout our study area. They approached recreationists to provide information and ask for their help with the study. This year, approximately 80% of the folks approached agreed to cooperate with the study by carrying a data logger, and of those, we had about a 70% return rate on the data loggers. This is lower than last year, but still an impressive show of support by the region's recreationists. Over the winter, we collected over 1,200 tracks of winter recreationists through this voluntary participation!

Diversity of Winter Recreation Information: Again this winter, we undertook a diversity of efforts to document winter recreation activities. As previously mentioned, the critical information we have gained through the volunteer participation of recreationists went exceptionally well. In addition, we established 30 infra-red trail use counters across the Payette-Boise NF study area and another 10 on the Sawtooth NF. These units provide great information on the total number of users passing by, and record this information for us 24/7 – providing us with excellent use. A preliminary evaluation of the trail use data shows that this was another busy year and the number of users leaving the major parking areas is similar or higher than last year. We are looking forward to delving into this information further in the 2011 Annual Report.

It is great to see that the recreation information that we are collecting is starting to be recognized for the value it has in documenting the popularity and importance of winter recreation in the area. We have had a request to potentially collaborate with the Avalanche Center to use some of our data to evaluate whether avalanche conditions alter the way folks recreate or where they choose to travel on those high avalanche days. This may assist the Avalanche Center in refining their avalanche monitoring and communication work to most effectively keep us aware and safe in the backcountry. We are considering this opportunity and will be discussing this further with our partners

7. **Investigating the Interactions Between Wolverines and Winter Recreation Use: 2010 Annual Report.** Heinemeyer, K., Squires, J. and Copeland, J. (2010) Round River Conservation Studies and U.S. Forest Service Rocky Mountain Research Station

<ins>Executive Summary:</ins> BACKGROUND AND MOTIVATION – Backcountry winter recreation is one of the fastest growing sectors of the recreation industry. This growing popularity combined with increasingly powerful snowmobile technology has resulted in winter recreation use expanding onto public forest lands that were largely undisturbed during winter months. This expanding recreational use is increasingly overlapping habitats preferred by wolverines during winter and reproductive denning seasons and may potentially represent a novel and growing impact on the species. The wolverine is currently being considered for listing under the Endangered Species Act and has been a species of management priority for National Forests and state wildlife departments throughout its current range in the United States. The

potential effects of winter recreation on wolverine reproduction, behavior, habitat use and ultimately, on populations are unknown and the management of winter recreation for wolverine persistence has little scientific foundation.

The Rocky Mountain Research Station, in collaboration with a number of government and non-government organizations, has initiated research to understand the interaction between wolverine and winter recreation. We are using a unique combination of approaches to simultaneously and intensively monitor both wolverines and winter recreation including GPS monitoring of wolverines and winter recreationists, and additional recreation monitoring through aerial surveys and trail use counts.

Project Goals and Approach: The over-arching project goal is to increase our understanding of the spatial and temporal interaction between winter recreation and wolverine habitat use, movements, and denning. Specific objectives of the research include: 1) assessing the spatial and temporal patterns of wolverine movements and habitat use relative to the distribution and relative intensity of recreation; and 2) investigating denning behavior in relation to recreation patterns.

The study is located in central Idaho including the Payette, Sawtooth and Boise National Forests. A significant challenge to any research on a rare species such as wolverine is the inherently low density of animals and subsequent small sample size. We will address this issue by establishing multiple study areas with each study area monitored for 1-3 years. The first study area was established north and east of McCall, Idaho in an area popular for backcountry winter recreation that also had confirmed presence of wolverines.

The goal and objectives of the project require that, from a logistical standpoint, two simultaneous and spatially-overlapping projects be conducted: an intensive monitoring of wolverines; and an intensive monitoring of winter recreation. During the first year of the study, we focused on the development and refinement of methodological approaches.

Wolverine Monitoring Methods and Results: Seven log box-traps were built during the fall and trapping was initiated on 8 January 2010. Traps were closed during early denning from late February through 20 March. Traps were re-opened through April to replace or remove collars. Captured wolverines were immobilized and instrumented with GPS collars that also had VHF beacon transmitters. Collars were programmed to recorded GPS locations every 20 minutes for 24-hour periods for 4 days each week. Two of these days represented higher recreation use days (Saturday, Sunday) and 2 days represented lower recreation use days (Tuesday, Wednesdays).

We captured and collared 3 adult female and 3 adult male wolverine. Over the course of the trapping season, all animals were captured at least twice and some animals were captured relatively frequently. The average number of trap-nights per wolverine capture was 11.2, with a total of 416 trap-nights and 37 wolverine captures through the season. In addition to wolverine, red fox (*Vulpes vulpes*) were captured 26 times (16 trap-nights/capture) and American marten (*Martes americana*) were captured 13 times (32 nights/capture).

Given the expected small sample size of wolverines from any single study area and year, we must be careful to not over-extend the analyses of the data. Thus, we have focused primarily on summarizing the data collected to date, providing initial data exploration and assessing and refining the usefulness of the field methods.

All 3 females initiated denning in mid- to-late February. One female (F1) stopped denning in March, and her teats were documented to dry up by late April. The other two females maintained dens throughout the monitoring period and were actively lactating when collars were removed in late April. Dens were visited during the summer to document evidence of wolverine presence and denning activity.

Minimum convex polygons (MCP) were calculated to estimate home range extent and overlap with winter recreation. The estimated home ranges for the 6 wolverines showed strong intrasexually-exclusive territories (i.e., territories are largely non-overlapping within a sex) but extensive intersexual overlap. Home range sizes varied, with female home ranges (ranging from 93.8 mi2 to 141.6 mi2) smaller than male home ranges (ranging from 170 – 383 mi2).

The locations of animals were used to calculate the distances moved, and from this, to calculate the hourly movement rates of animals. This information was used to look for patterns in diel activity within and across individuals. Movement rates varied by individual wolverine, but overall, males had higher average (+ st. dev.) movement rates (4380.9 + 1404.4 m/hr) than females (1393.8 + 855.9 m/hr). There is a general pattern of higher movement rates during daylight hours implied by the average movement rates of males and females classified by light conditions. One female (F2) showed a shift in hourly movement rates to move more during night and early morning hours during denning compared to pre-denning movements. The movement rates and daily distance travelled by the two females that maintained dens increased through time and were eventually higher than those observed during the pre-denning.

Winter Recreation Monitoring Methods and Results: We implemented and evaluated 4 independent and complementary methods to gather data on spatial and temporal recreation use across the study area: GPS tracking of recreation groups; aerial surveys; trail use counts; and, parking lot vehicle counts. Parking lot counts were of minimal utility compared to other methods, and we do not present parking lot information in this report to focus on more informative data.

To collect GPS tracks of recreationists, we identified access points commonly used by winter recreationists and stationed 1-2 technicians at a parking lot to ask recreationists to in carrying a small GPS data logger. We undertook the sampling on Saturday and Sunday as relatively high recreation days and Tuesday and Wednesday as relatively low recreation days. Over 90% of the recreationists asked to carry a GPS data logger were willing to do so and the return rate of the units was also over 90%. In addition, we collected GPS tracks of guided cat-skiing that originated at Brundage Ski Resort. Between early January and mid-April, we collected 714 GPS tracks carried by recreationists in our study area. Of these, 34 tracks were backcountry skiers, 12 were backcountry snowboarders, 24 were from the guided cat-skiers and 644 were snowmobilers. The average size of recreation groups varied by type of recreation with the guided cat-skiers having the largest groups (9.9 people per group), the backcountry skiers having the smallest group size (2.9 people) and the snowmobile groups averaging 4.6 people. The number of recreationists represented by a GPS unit averaged 1.7 people/GPS for backcountry skiers and 3.2 people/GPS for snowmobilers. Overall, the 714 tracks represent monitoring of a sample of 2,398 recreationists clustered into 539 groups. The cumulative spatial density of recreation intensity through the field season varied across the study area with the highest density recreation in the Goose Lake area, and more generally, higher density recreation along groomed routes and closer to access points.

We used aerial surveys as an independent data source to validate the relative intensity of recreation use across the study area indicated by the GPS monitoring of recreationists. We also used aerial surveys to identify the spatial extent of the recreation footprint, which we might expect to be under-estimated with the GPS monitoring of a sample of recreationists. To remove potential observer biases, we used repeated presence-absence observations to score the relative intensity of recreation use across the study area. The sampling was conducted based on a grid of 6.25 km2 (2.5 km x 2.5 km) cells with 30-second intervals between sequential observations that allowed an average of 3 independent observations within each grid cell. The relative intensity of recreation use within each grid cell was scored as the number of “presents“ out of the total samples taken within each cell. Over the course of the winter, 3 aerial surveys were completed. The observed relative intensity of recreation across the study area estimated by the aerial surveys is reflective of the GPS recreation track sampling. As expected, the aerial surveys generally show a larger recreation footprint with some sampling units showing recreation use in areas where there are no GPS samples.

Infra-red trail use counters (trial counters) provided our third primary source of data on recreation use. We established 20 trail counters along snowmobile routes and on access routes for backcountry skiers. The counters were programmed to summarize the number of times the infra-red beam was broken each hour and we assume each count represents a recreationist. Here, we focus on data from 5 of the trail counters that best represent the number of recreationists entering the study area from the 3 primary access points. We assumed that each recreationist entered and left the study area by the same route on the same day and is double-counted in the data. Therefore, we divided the hourly counts by 2 to estimate the number of recreationist that travelled by any trail counter. Over the monitoring period (January 20 – April 27), 7,014 recreationists are estimated to have accessed trails north of the Upper Elevation Parking area, 6,595 were recorded on roads and trails likely accessed by the Warren Wagon Road parking area, and 549 were recorded along the Lick Creek Road. Saturday had the highest daily averages and Saturday averages were highest in February, when an average of over 200 winter recreationists estimated to be using each of the Upper Elevation Parking area and the Warren Wagon Parking Area. Peak activity for backcountry skiers using the Lick Cr Road was also highest on Saturday with an average of 10 recreationists/day in January and February. Use declined in March and April with the lowest daily averages in April. The lowest recreation days were Monday and Tuesday with each day representing less than 10% of the weekly use for both snowmobile and non-motorized recreation activities. For both types of recreation, there is a peak in activity at 1000 hours, as people left trailheads to enter the study area, and an additional peak in activity at 1600 hours, as people are returning to trailheads and passing by the trail counters for a second time.

Preliminary Results of Wolverine and Winter Recreation Patterns: With only a single year of data on 3 female and 3 male wolverines, limited analyses can be done and conclusions cannot be reached regarding any potential interactions between wolverines and winter recreation. Still, the monitoring indicates that the home range boundaries estimated for the 6 wolverines contained variable amounts of winter recreation including areas of the highest intensity recreation as well as large areas of no recreation use. The home ranges of 4 animals contained extensive recreation use, with recreation intensity ranging from high to nil within different regions. The home range of 2 other animals contained low levels of recreation based on our recreation monitoring efforts. The den sites chosen by two females were within landscapes that support lower levels of recreation intensity, but were within several hundred meters of pockets of higher recreation activity. The den site of the third female was within an area with no recreation activity.

There appears to be no difference in wolverine movement rates between high recreation days (i.e., Saturday and Sunday) and lower recreation days (i.e., Tuesday and Wednesday). Movement rates of 2 females show a daily pattern of low movement rates during peak recreation times. The third female had no recreation within the large drainage where her den was located and had increased movement rates during daylight hours.

Conclusions and Next Steps: We had high success in all the field methodologies we invested in. In particular, the quality and amount of data provided by the intensive GPS monitoring of recreationists, combined with the aerial surveys and the trail counters, provides an unparalleled opportunity to investigate potential interactions between wolverine and winter recreation. Data analyses will be on-going, and will require additional years of data to increase sample size and evaluate potential variability in responses. This initial year has shown the utility of the study design and field methods. It has also provided an initial opportunity to evaluate questions regarding potential interactions between wolverine and winter recreation.

The study will be repeated in the McCall, Idaho study area during the winter of 2011. In addition, we will be expanding the study area to the south onto the Boise National Forest in the Warm Lake area with the establishment of additional trapping and recreation monitoring. We are also initiating a study area on the Sawtooth National Forest near Stanley, Idaho. Refinements to the study design, based on the information presented here, will be incorporated into the efforts in 2011.

8. **Central Idaho Wolverine - Winter Recreation Research Project: Summary.** Heinemeyer, K., Squires, J. and Copeland, J. (2009) Round River Conservation Studies and U.S. Forest Service Rocky Mountain Research Station. http://wolverinefoundation.org/wp-content/uploads/2011/02/ciwp_20Dec09.pdf

Project Description: This project will undertake research to increase our understanding of potential interactions between winter recreation and wolverine demography and habitat use. In the first phase of this effort, winter aerial surveys were undertaken in 2008 to provide information on the distribution of wolverine and both motorized and non-motorized winter recreation across the 3 National Forests (Copeland et al. 2009). These surveys indicated that, at a regional scale, there are areas of extensive recreation use within potential wolverine denning habitat, and also that, in some of these areas, wolverine are present (Figure 2).

Phase II of the project will focus on understanding the spatial and temporal interactions between wolverine and recreation within these regions of overlap.

This Phase of the study will focus on an area north and east of McCall, Idaho, that was identified during the Phase I surveys as an area of known wolverine presence overlapping both snowmobile and backcountry ski recreational uses (Figure 3). After 2 years of focused effort in this study area, it is anticipated that the project would either move or expand to other suitable areas within the central Idaho region.

The over-arching goal of the proposed research project is to: *Increase our understanding of the spatial and temporal interaction between winter recreation and wolverine habitat use, movements and denning.*

Specific project objectives include:

- Document potential high quality habitats for wolverines across the study area
- Understand the spatial and temporal patterns of recreation use, including the distribution and intensity of use
- Assess the spatial overlap between winter recreation and wolverine potential habitats and known winter home ranges
- Assess the spatial and temporal patterns of wolverine movements and habitat use relative to the distribution and relative intensity of recreation use
- Document denning behaviors and locations, particularly in relation to recreation patterns

Most importantly, increasing our scientific understanding of the potential effects of winter recreation should provide managers increased flexibility in developing management recommendations and help ensure that both wolverine and winter recreation are healthy and sustained values in the Rocky Mountains.

The project will focus on understanding the spatial and temporal interactions between wolverine and winter recreation. Intensive GPS tracking of both wolverines and winter recreationists will provide data matched in space and time. This will allow us to examine wolverine responses to varying levels and types of recreation, including spatio-temporal overlap at local scales and monitoring a diversity of wolverine response indicators, such as shifts in habitat use and movement patterns relative to the distribution and intensity of recreation across seasonal, weekly and daily periods.

East Slopes Predator Project – Alberta, Canada

1. **East Slopes Predators: Mammalian spatial distribution and habitat selection in a heterogeneous mountain landscape, Year-End Report 2011-2012.** Fischer, J.T. & Heim, N. (2012) Alberta Innovates Technology Futures http://wolverinefoundation.org/wp-content/uploads/2011/02/esp_yerf_2012.pdf

Project Summary: Alberta's East Slopes are a unique mosaic of protected areas, oil and gas development, recreational activity, forestry, and grazing land. The Slopes are also home to a diverse predator community, including grizzly and black bears, wolves, cougars, and wolverines, among others. Although the Rocky Mountains anchor predator populations, some species are known (grizzlies) or suspected (wolverines) to be declining. Oil and gas activity is often cited as a primary stressor on predator populations, but combined landscape footprints from multiple human activities, including recreation and road access, likely have cumulative effects on predators. The relative contribution of each of these sectors is controversial, and need to be discerned to allow effective management. Therefore, research that investigates how different human activities and footprints affect landscape-scale predator occurrence will inform long-term conservation of predator communities. To meet this goal, we are surveying predator occurrence (grizzly bear, black bear, wolverine, fisher, lynx, cougar, wolf, *etc.*) on the East Slopes using non-invasive detection methods, with a more in-depth focus on wolverine genetics. We will model the occurrence of predators in relation to natural habitat features and landscape alteration *via* (1) commercial forestry; (2) oil and gas development, including seismic line density; (3) recreational activity, including off-road vehicle routes; (4) livestock grazing and other agriculture; and (5) roads. We will examine the relative contribution of each landscape activity in explaining predator occurrence, and identify key stressors for each species, to inform management of landscape development that will allow effective carnivore conservation.

Greater Yellowstone Wolverine Program

1. **Progress Report – December 2009** http://wolverinefoundation.org/wp-content/uploads/2011/02/WCS_WP_Progress_Report_Dec_2009.pdf

Research Summary: We started the 2008/2009 winter season with 11 wolverines on the air, 6 of which were adult females. As a result of our den survey efforts during spring 2008, we also had information on areas that may hold an additional 18 wolverines – 10 adult females, 5 adult males, and 3 dispersing-aged wolverines. Based on the locations of these unmarked wolverines we ran a small but targeted capture effort during December '08-February'09. These efforts resulted in 7 wolverine captures (5 new captures, 2 recaptures) during a total of 138 trap-nights (1 wolverine capture/20 trap-nights for this targeted effort). One of these individuals was not radio-implanted due to a heart condition. We also radio-implanted and GPS collared an additional wolverine that was incidentally captured by a recreational trapper on Menan Buttes in Idaho, and we recaptured a dispersing-aged female in Montana. A total of 7 wolverines were handled during the winter, including 6 new individuals. At present we are radio-monitoring 9 wolverines (5 adult females, 3 dispersing-age wolverines, and 1 adult male). We lost 4 due to expiration of their implant batteries (3M 1F), and are currently unable to relocate another 4 (2M 2F) who have either moved large distances or their implants have failed prematurely.

We adapted our handling protocol to include use of a pulse-oximeter, administration of oxygen, and improved thermal regulation. We also decided to end targeted box-capture efforts by February 15 in areas known to contain reproductive aged females in order to avoid capturing late-term pregnant females and/or lactating females with cubs.

This spring's den detection test was successful in that the blind search using the fixed-wing technique matched exactly with what the telemetry and follow-up data indicated. However, it was less informative than we had hoped because both techniques indicated that none of the 6 adult females successfully reproduced this year. So, although the technique determined what actually happened, we did not come away with a den detection rate. So the question remains – If 10 wolverine dens are present, how many can we detect with blind, fixed-wing surveys? We were however able to show that the technique can provide a relatively inexpensive method of aerial track detection and thus wolverine distribution.

Over the spring/summer we monitored 3 individuals during their dispersal movements. This included the movement of a subadult male from northwestern Wyoming to Colorado, making him the first confirmed wolverine in Colorado since 1919.

During calendar years 2008 and 2009 we radio-monitored 20 different wolverines for a total of 23-wolverine-years. This included reproductive observations of 7 different females during a total of 12 reproductive opportunities with one reproduction documented (1 cub of unknown sex). We also recorded one mortality during this period (a juvenile male).

2. **Progress Report – November 2008** http://wolverinefoundation.org/wp-content/uploads/2011/02/WCS-WP-Update-Nov-2008.pdf

Excerpt: GPS Collars on 5 Adult Female Wolverines Provide Valuable Data Related to Winter Recreation; during the winter of 2006-07, we were able to place GPS collars on 5 adult female wolverines. These collars were provided Montana Dept. of Fish Wildlife and Parks. The collars were programmed to collect a location once every hour. We obtained a total of 2,066 locations of the 5 females. So we ended up with over 75,000 5-min samples of wolverine activity level (some reported in McCue et al. 2007).

The data from these collars provides further evidence that wolverines utilize their exceptionally large annual home ranges over a very short period of time (on the order of weeks: Fig. 7) The data also provide further evidence for territoriality (Fig. 7 bottom middle). More importantly, we can use these data to compare movement rates, activity patterns, and locations of these females in relation to winter recreation (snowmobiles and ski activity).

3. **Greater Yellowstone Wolverine Program Update: December 2006—March 2007.** Inman, B., & McCue, T. (2007) Wildlife Conservation Society. http://wolverinefoundation.org/wp-content/uploads/2011/02/gyws06-07.pdf

Summary: This winter we focused on the Montana region of our study area. Our goal was to replace aging transmitters and instrument all females with GPS collars. The winter trapping effort began December 28 and ended March 15. One field crew operated 11 traps in the Madison, Gravelly, Henrys Lake, and Centennial Ranges for a total of 371 trap-nights. We recaptured 5 female wolverines a total of 9 times. Implants were replaced and each was fitted with a GPS collar. We did not capture any new individuals.

Report includes a photo that shows an important aspect of the wolverine/winter recreation interaction that we would like to learn more about. F121's natal densite is marked with the arrow on the right. The snowmobiling shown in the picture occurred while the den was active (relatively close to the densite). She has remained at this densite to date.

We have started our spring effort to collect reproduction data. Only one of our seven radioed adult females has given an indication of denning this spring. We will continue to monitor all of the females throughout the spring and early summer to verify their reproductive status. On 2/28/07 we verified the location of F121's den in the Gravelly Range. We will attempt to capture the kits in May.

We are also searching the north end of the Teton Range for a den site from the female we believe is occupying this area. Other areas scheduled to be searched for possible den sites are the Snowcrest, Gallatin, and Snake River Ranges.

We documented one mortality during this update period. F405, a known age female captured as a kit in the Teton Range, was killed in an avalanche in Grand Teton National Park in mid-December.

The kit we captured last spring, F133, is currently dispersing. F133 spent the majority of last summer in the north end of the Gallatin Range. Beginning in the fall, she starting spending more time in the southern portion of the Gallatin. In late February she began showing signs that she might disperse with a move to the southern tip of the Gallatin Range. Her first move outside the Gallatin was to the Madison Range across US Highway 191 in Yellowstone National Park (YNP). We were able to document the location where she crossed back into the Gallatin Range a few days later. After a short stay in the southern Gallatin, her next location was in the Thorofare Creek area southeast of YNP. We will attempt to monitor her throughout her dispersal.

4. **Greater Yellowstone Wolverine Program Update: December 2005—February 2006.** Inman, B., & McCue, T. (2006) Wildlife Conservation Society. http://wolverinefoundation.org/wp-content/uploads/2011/02/gyws05-06.pdf

Excerpts: Recreation Monitoring: Jenny Bell was once again conducting recreation surveys around the Madison, Gallatin, and Gravelly mountain ranges. Parking area surveys (vehicle and snowmobile trailer space counts), parking area validations, and trail counters are being utilized to develop a technique to monitor levels of winter recreational use. Recent analysis of recreational data has helped us identify areas to improve our survey methodology. We determined that trail counters can more accurately assess recreational use in areas where snowmobiling does not originate at a central parking area and at ski areas where peak time parking lot counts are not as effective. The number of trail counter validations was increased to estimate and assure counter accuracy. Twice weekly, parking area surveys were performed during peak hours at high use areas. Frequency of parking area validations was also increased to approximately two per week. Validations are conducted by stationing an observer at one parking area all day to record the number of vehicles, snowmobile trailer spaces, snowmobiles on each trailer, and/or skiers in each vehicle along with entry and exit times of users. The purpose of increasing parking area validations was three-fold: first, to accurately predict the number of actual snowmobiles represented by each trailer space, or the number of skiers represented by each vehicle; second, to determine the peak hours of parking area use; third, to determine the amount of day-long parking area use that is represented by peak hours. We increased the sample size of parking area validations due to their importance in estimating actual user numbers from survey results. This improvement in sampling accuracy will enhance our ability to determine annual rates of change in winter recreational use at each site.

5. **Absaroka-Beartooth Wolverine Project: Spring 2006 Newsletter.** Copeland, J., Murphy, K., & Wilmot, J. (2006) The Wolverine Foundation.

Project Overview: The Absaroka-Beartooth Wolverine Project began this past January in the eastern portion of Yellowstone National Park and on the Shoshone and Gallatin National Forests. The project, which is a cooperative effort developed by Yellowstone National Park and the Forest Service's Rocky

Mountain Research Station, is designed to increase our understanding of one of the rarest carnivores in North America. Prompted by elevated public concerns regarding the presence, abundance, and status of wolverine across the northern Rocky Mountains, researchers hope to aid management by clarifying the wolverine's dependence on habitats in Yellowstone National Park and surrounding National Forest lands. The project will study wolverine distribution and movements, habitat and food associations, and population indices such as survival rates, birth rates, and dispersal movements. Also, we seek to clarify the wolverine's relationship with other carnivores in the Yellowstone ecosystem.

Wolverine will continue to be live-trapped using log box traps and instrumented with implant transmitters, and in some cases, GPS collars capable of collecting high precision, fine-scale information on wolverine movement and habitat use. The project is designed to operate in and around Yellowstone National Park through a 4-year study period with primary funding support provided by the Yellowstone Park Foundation and the Forest Service.
Twenty-seven log box-traps border the rugged Absaroka-Beartooth and Gallatin Mountain ranges in northern Wyoming and southern Montana. The traps are designed to lure the rare and elusive wolverine to the promise of a fresh meal of beaver and venison. The wolverine inhabits the most rugged, inaccessible country in the western United States. Its lifestyle demands that it remain in almost constant movement in search of a food source that is rarely predictable and often little more than hide and bones—a situation researchers hope to exploit with their well-stocked bait sites. Wolverine occur at naturally low densities (generally about 1 wolverine/150 km2) and exhibit a tenacious adherence to daily foraging routines. This makes wolverine trapping a tenuous undertaking. "Wolverine captures will be rare and unpredictable with success requiring diligence and constant attention to detail," says Jeff Copeland, Rocky Mountain Research Station biologist and co-principal investigator on the project.

In early 2006, four trap lines operated for a total of 1,827 trap nights that produced 71 red fox, 41 American marten, and 2 wolverine captures. Both wolverines were adult males; M1 was captured on the Gallatin Forest just north of the park, and M2 was captured near Sylvan Pass on the eastern interior of the park. Both individuals were implanted with a VHF transmitter and fitted with a GPS collar. Unfortunately, both individuals have since shed their collars due to apparent collar malfunctions. However, data collected and stored on the collars has been retrieved, providing insight into the daily movements of both individuals. VHF implant transmitters will provide continued contact with the animals through aerial and ground-based telemetry, which will continue throughout the year.

Male M1 was instrumented with a GPS collar on March 22. His collar began collecting data early on the morning of March 23. Over the next 26 days his collar collected 194 locations as he traveled 453 kilometers across the Gallatin National Forest. The collar was programmed to attempt a GPS fix every 2 hours, which would have tallied 308 locations for this period. The 194 locations collected represent a fix success rate of 63%. While he was on the move, M1 traveled at a rate of 1.4 km/hour. During one articular 2-hour foray on March 31, he moved 9.1 kilometers.

6. **Wolverine Population Assessment in Glacier National Park: Spring 2006 Progress Report.** Copeland, J.P. & Yates, R.E. (2006) USDA Forest Service, Rocky Mountain Research Station, Missoula, MT.

Executive Summary: The Glacier National Park Wolverine Project has just completed its third full year of study. During that time, 19 wolverines have been captured and instrumented providing over 3,000 telemetry-location points. Reproductive den sites, documented for two adult females, occurred on upper slopes in sparse timber beneath downed, woody debris. Females used 2-3 dens prior to weaning of kits. These dens represent nearly 50% of all wolverine dens ever found in the continental U.S. Four kits were captured and instrumented at den sites and monitored through their first summer to document 17 rendezvous sites; these occurred primarily in boulder talus and cliff areas. Kits separated from their

mother at 6-7 months-of-age in late September. Kit survival to adulthood has been low as evidenced by 3 of 4 kits dying during their first year. GPS collars were tested at 4-hr, 2-hr, 30-min, and 5-min fix acquisition intervals providing insight into capabilities of documenting patterns and rates of movement, habitat use, and social interactions. GPS data from 2 males indicated movement rates averaging 2 km/hr in a pattern of long-distance movements (commonly exceeding 10 km) interspersed with localization periods of up to 20 hrs. Wolverines traverse the landscape apparently indifferent to topographic features. Glacier National Park wolverine home ranges averaged 496 km2 for males and 141 km2 for females. DNA analysis for 20 individuals suggests less genetic structure than expected with relatedness contained by 2 distinct genotypic groups within our study population.

The 3-year study period provided by the Natural Resources Protection Program grant ended in 2004. Glacier National Park and Rocky Mountain Research Station staff met in 2005 and agreed to continuation of the project for 3 additional years pending funding. Additional funding provided by agencies, private grants, and private donations will allow continuation into FY 2007.

Mortalities — Both 2004 kits died during their first year. One was legally taken by a trapper outside the park boundary, and the second of unknown cause at approximately 9 or 10 months of age. One of the 2005 kits was killed by an unknown predator at 8 months of age. A 3-year-old female (F5) died in an avalanche in 2005. We are currently conducting a formal survivorship analysis of our study population.

In our 2004 progress report, we described the disappearance of subadult male M8. Believed to be a yearling at capture in February 2004, M8 left GNP about a week after capture. He moved into the Whitefish Range near Hungry Horse at which time we began closely monitoring his movements. He disappeared from the Whitefish Range in early April, in spite of efforts to maintain daily contact. In late July, researchers conducting a grizzly bear flight in the northern portion of the Kootenai National Forest detected M8's telemetry signal. The bear researchers continued to monitor M8 near American Creek and the Northwest Peaks Natural Area until he was legally taken by a trapper in December 2004. He had traveled over 200 kilometers as measured by straight-line distance.

7. **Greater Yellowstone Wolverine Study, Cumulative Progress Report December 2003.** Inman, K. H., Inman, R. M., Wigglesworth, R.R., McCue, A.J., Brock, B.L., Rieck, J.D. and Harrower, W. (2003) Wildlife Conservation Society General Technical Report. http://wolverinefoundation.org/wp-content/uploads/2011/02/2003.pdf

Abstract: The status of wolverine populations in the lower 48 remains uncertain and the ecological requirements of the species are not well described. Federal and state resource managers need information in order to make well-informed policy decisions that affect land-use practices and populations of wolverines. This project is designed to provide baseline ecological data and answer specific questions relevant to wolverine management and related land-use policies (i.e., does winter recreation impact wolverine reproduction, where are critical habitat and travel corridors, and are fur trapping practices sustainable). Two areas, the Madison Focal Area of southwestern Montana and eastern Idaho (MFA) and the Teton Focal Area of northwestern Wyoming and eastern Idaho (TFA), have been selected for intensive study. These areas are representative of the land management jurisdictions and human-use impacts common to the Greater Yellowstone Area (GYA).

To date we have constructed 53 log box-traps in Montana, Idaho, and Wyoming. Eighteen different wolverines (9 female, 9 male) have been captured and 10 (6 female, 4 male) are currently radio-instrumented. Seven wolverines were fit with store-on-board GPS collars, and one was fit with a satellite collar. Success and failure of collars is discussed below. We have obtained 921 VHF and GPS locations of wolverines.

We have documented four causes of wolverine mortality: avalanche, trapper-harvest, interspecific competition (black bear), and vehicle collision. Three adult males have died from non-human-related mortality sources, and a subadult female, an adult female, and an adult male from legal harvest. Data suggest that four females have given birth, between Feb.14-24. One natal den was located at approximately 2,200 m elevation (7,200 ft) in an area of mixed conifer stands, the second was at 2,750-3,000 m elevation (9,000-10,000 ft) on a north facing slope.

More specific habitat information will be available at a later date. We have not yet documented the presence of kits with 100% certainty. Doing so, along with documentation of reproductive den habitat, is of highest priority this spring. Although sample sizes for all reproductive analyses are extremely small at this point, pregnancy rates of females more than 2 years old averaged 67% (n=6) and has varied by year (50-100%). We estimated age at first reproduction to begin at 3 years of age; 0% of one-year olds (n=6), 0% of two-year olds (n=3), 50% of three-year olds (n=2), and 100% of 4+ year olds (n=7) showed evidence of reproduction. Percentages of females more than 2 years old giving birth averaged 40% and has varied by year (0-100%, n=5).

Adult female 100% MCP (Minimum Convex Polygon) home range size averaged 754 km^2 (3 wolverines, 202 locations) while sub-adult females averaged 429 km^2 (5 wolverines, 213 locations). Adult male home ranges averaged 910 km^2 (5 wolverines, 231 locations) and a single sub-adult male had a home range of 629 km^2 (1 wolverine, 24 locations). M304's movements and home range appear to be that of a dispersing male and 251 locations yield a 100% MCP home range estimate of 37,638 km^2. Fixed Kernel (95%) estimates are also provided for animals with more than 30 locations. Two sub-adults (1 female, 1 male) appear to have shifted home ranges in response to the death of a same-sex adult. Although statistical tests have not yet been performed, it appears that wolverines use higher elevations (greater than 6,890 ft), steep slopes (greater than 16°), NW and N aspects, evergreen forest, bare rock, and perennial ice and snow disproportionately to their availability.

Pilot season data on winter recreation indicated that peak hours of snowmobile and ski activity occurred between 11:00-15:00, and that mean amount of use differed between weekdays and weekends (P 0.005). After analysis of parking area data from the pilot season, we classified mean levels of use as low impact (15 trailer spaces), moderate impact (16-40), and high impact (41-80). A recreational flight survey technique was developed and tested on the MFA and then used on the TFA. We conducted one survey of 2,523 km^2 for distribution of snowmobile and ski use on the MFA and one survey of 3,059 km^2 for snowmobile and ski use on the TFA during Feb 2003. On the MFA, 18% of the area was impacted by snowmobile use (11% highly impacted), and 4% was impacted by ski use (2% highly impacted). On the TFA, 36% of the area was impacted by snowmobile use (1% highly impacted), and 9% was impacted by ski use (1% highly impacted).

8. **2002 Annual Report** http://wolverinefoundation.org/wp-content/uploads/2011/02/2002.pdf *(Note: substantial new information has been learned about wolverines since these early studies)*

9. **2001 Annual Report** http://wolverinefoundation.org/wp-content/uploads/2011/02/2001.pdf *(Note: substantial new information has been learned about wolverines since these early studies)*

10. **Aerial Surveys for Wolverine Presence and Potential Winter Recreation Impacts to Predicted Wolverine Denning Habitats in the Southwestern Yellowstone Ecosystem.** Heinemeyer, K. & Copeland, J. (2001) Department of Environmental Studies – University of California Santa Cruz, Idaho Department of Fish and Game, and Targhee National Forest.

Introduction: Wolverines (*Gulo gulo*) are rare, medium-sized carnivores that historically inhabited forested regions across the northern tier of North America. Their distribution included much of Canada, southward into United States from Maine to Washington State. Southward, wolverine extended down the Cascade Mountains of Oregon and into the southern Sierras in California, and down the Rocky Mountains into Arizona and New Mexico (Grinnell et al. 1937, Banci 1994, Hash 1987). The wolverine has experienced dramatic reductions in their southern distributional extent. In the United States, their present distribution is restricted to the Rocky Mountains, and only Idaho, Montana and Wyoming are known to support populations. The wolverine is considered extirpated or at extremely low numbers in the Pacific States and the southern Rocky Mountains. Even in northern US Rockies, we know very little about the extent and status of wolverine populations.

We have little understanding of the historical and current impacts to wolverine populations. Some historical threats may continue to threaten wolverine populations, including habitat alteration and population isolation. Additionally, new threats place novel stresses on the remaining populations. One relatively new potential impact is winter recreational use of natal denning habitats. Female wolverines appear to prefer high elevation, north-facing talus slopes for natal denning. Often located within cirque basins, the females occupy extensive snow tunnels that form a complex of dens (Magoun and Copeland 1998). These dens are occupied during the early spring (February – April) birthing and whelping periods. There is a growing body of evidence that females are prone to disturbance at den sites, particularly at the natal dens where birthing occurs. Idaho wolverine selected specific natal and kit rearing habitat and responded negatively to human disturbance near these sites (Copeland 1996). Female wolverine abandoned dens in Finland (Pulliainen 1968) and Norway (Myrberget 1968) when disturbed by human activity.

Both snowmobile use and backcountry ski use has seen rapid increases in popularity over the last several years. Advancements in the power and technology of snowmobiles have resulted in machines and riders that can readily access what was previously viewed as inaccessible areas due to the rugged terrain. Extreme snowmobilers, who use the steep slopes of the cirque basins as playgrounds, favor these remote areas. Unfortunately, it is during the wolverine denning season (February – April) that we may see the highest or most intense recreational use of denning habitats (i.e., cirque basins), by both snowmobilers and skiers. Spring snow pack provides the most favorable conditions to access the remote regions, and it is exactly during this time when these recreationists will most negatively affect reproductive activities of resident wolverines. As snowmobiling and backcountry skiing continues to grow in popularity, there is an increasing concern that reproductive habitats may become limiting to populations due to human disturbance. Protection of reproductive denning habitat may be critical for the persistence of wolverine. An association between wolverine presence and refugia (e.g., Wilderness Areas) may be linked to a lack of available reproductive denning habitat outside protected areas.

Discussion and Recommendations: While the actual percentage of denning habitats with snowmobile activity appears low, particularly in comparison with last year’s results, this is due primarily to having a much larger amount of predicted habitats in the study area. The spatial extent of the recreational activity on the TNF appears similar between 1999 and 2000. The areas most impacted by recreational activities are the Targhee Creek, East Centennials and Palisades SUs, with the Teton Range receiving some heavy localized use. These areas warrant careful management consideration if maintenance of potentially critical wolverine reproductive habitat is desired. Below, we discuss each of these areas.

The Targhee Creek SU has the most intensive snowmobile use across the study area. Last year we located a potential wolverine den in the single small basin that was free of snowmobile activity. This year, we saw high levels of wolverine activity in this same general area, which was again without snowmobile activity. We also located wolverine tracks throughout the Targhee Creek SU, but never within areas of high snowmobile activity. Additionally, we did not find any foraging behaviors (e.g., digs, meandering paths) in areas with snowmobile activity. This may indicate that not only are wolverine sensitive to recreational use near denning sites, but also need secure areas for foraging activities. It is interesting to note that wolverine in this area were found digging for whitebark pine seeds, and we wonder if the limited amount of secure foraging habitat forced animals to seek inferior, alternative food sources in areas free of snowmobile use. We also followed a set of wolverine tracks from this area along the Miles Creek drainage down to open country at its mouth, where there are known elk wintering grounds. We lost the tracks in the low elevation, crusted snow, and do not know if it was seeking or feeding on carrion in this atypical wolverine habitat. Again, it appears that snowmobile activity may be forcing this individual to resort to possibly atypical or risky behaviors to meet winter food requirements.

The East Centennial SU also supports extensive snowmobile activity, but little of this recreational activity occurs in the predicted wolverine denning habitats. Most of the predicted denning habitat occurs along the north face of the range, and is primarily a series of steep avalanche chutes. We found no wolverine tracks along this north face, and the characteristics of these predicted habitats do not appear to form high quality wolverine denning habitat. We did find several wolverine tracks along the broad top of the Centennial Range, and along the south-facing portions of the mountains. This same region of the mountain range was heavily impacted by snowmobiles. Yet, again, most tracks were found in areas with little snowmobile activity, although some tracks did move through areas with high intensity snowmobile activity. Similar to Targhee Creek, tracks in areas with snowmobile activity showed little deviation from a straight path, indicating that the animal was willing only to travel through these used areas. Most of the predicted denning areas not located on the north face were impacted by snowmobile use. If the avalanche chutes on the north-face are not truly denning habitat, then the small amount of denning habitat available in the East Centennial SU is impacted by high intensity snowmobile use.

We found a single set of wolverine tracks on Saddle Mountain in the East Centennial SU. This lone mountain may provide a linkage corridor between Targhee Creek and the East Centennials. Snow conditions did not allow us to follow the tracks to confirm that this animal was moving between the two mountain ranges. In an earlier survey, we did find a single set of tracks traveling through Hell Roaring Canyon, at the base of Sawtell Peak and in an area heavily impacted by snowmobiles. There is the possibility that this drainage forms part of a movement corridor connecting Targhee Creek and the Centennial Mountains via Saddle Mountain.

As was noted in 1999, the heli-ski operation in the Palisades SU impacts a substantial portion of the predicted denning habitats in the area. When combined with the extensive snowmobile use in this area, denning habitats are widely impacted across the Palisades region (approximately 27%), more heavily impacted than even the Targhee Creek SU. We have not found evidence of wolverine presence in the Palisades after 2 years of surveys. We would recommend that at least another year of survey, and preferably multiple surveys be conducted in this area. The region appears to contain high quality wolverine habitat, but these habitats appear to be incurring potentially large impacts due to the widespread winter recreational activities.

Winter recreational use, particularly snowmobile and heli-skiing, may be having potentially severe localized habitat impacts on wolverines. While the impact on populations due to removal of critical denning habitats is more obvious, these recreational uses may be placing additional impacts on wolverine populations by removing foraging habitats as well. Management of snowmobile and heli-skiing is warranted in areas with significant amounts of potential denning habitat, and should include access restrictions during the denning period (February – April).

We recommend future research efforts focus on the winter ecology of wolverines and the impacts of winter recreational activities on individuals and populations. The study area we have examined may provide excellent research opportunities, with the extensive and variable nature of the snowmobile and ski activity across the region. This area has additional advantages in providing naturally and anthropogenically fragmented landscapes and wolverine populations. This provides the unique and critical opportunity to collect data on large-scale animal movements and landscape connectivity. We have documented what we believe is an animal moving between Targhee Creek and the East Centennial via Slide Mountain. Additionally, we documented a single track moving through the north end of the Italian Peaks in 1999, and a single track in the Gravelly Mountains this year. We do not know if the tracks belong to resident animals or to animals using these habitats to move to larger blocks of habitats. Obtaining information on landscape connectivity will be critical for population maintenance of wide-ranging species such as wolverines. The knowledge gained by such research will have application across a diversity of landscapes, including those artificially fragmented by human development and land management practices.

North Cascades Wolverine Study

1. **Wolverine Distribution and Ecology in the North Cascades Ecosystem Final Progress Report – 2016.** http://wolverinefoundation.org/wp-content/uploads/2011/02/NorthCascadesWolverineStudy_Final-Progress-Report2012-2016.pdf

Results: *Live-trapping*—In Washington, we operated 2 to 5 traps during the first 3 years (Table 2). Since the 4th year of the study (winter 2008/09), we've operated 7-12 traps each winter depending on our project objectives and available resources (Table 2). In most years, the trapping season began in January and continued into late-March or early April; however, during the past 4 winters (2011/12 thru 2014/15), we began trapping in early December. Some trap sites take longer to open at the beginning of the season than others (i.e., it takes longer to establish a safe snowmobile route), and there are occasions when we periodically need to close traps due to high avalanche danger. Thus, in any given winter, the number of trap nights can be much lower for some traps than others (Table 2). To date in Washington, we have operated traps for a total of 4,781 trap nights during 10 winter field seasons, and have live-captured 13 different wolverines on 39 occasions (Table 2). Non-target species captured included Canada lynx, marten, and bobcat; all were released unharmed. Although we detected 5 different wolverines at our trap sites this past winter (2014/15), we only captured 1 male. An unusually warm winter with a corresponding low snowpack (the snowpack was 16% of normal for Washington; http://earthobservatory.nasa.gov/IOTD/view.php?id=85887) may have been a contributing factor to the low capture rate we experienced.

Our collaborators in British Columbia operated most of their 10 livetraps for 17-20 days during the winter of 2008/09 (year 4), but did not capture any wolverines. During the winter of 2009/10 (year 5), they operated 12 livetraps from 7 January to March 22 for a total of 472 trap nights and captured 2 adult wolverines that had been captured previously in Washington. During the winter of 2010/11 (year 6), they operated livetraps for varying number of days from 12 January to 5 April, but did not capture any wolverines. During the winter of 2011/12 (year 7), they operated 9 livetraps for a total of 538 trap nights and captured 1 new female on 2 occasions. No livetraps have been operated in British Columbia since the winter of 2011/12. Thus, in British Columbia, we captured 3 individual wolverines during a 4-year period: 2 that were previously captured in Washington (Rocky and Melanie) and 1 that was new to the study (Kendyl). Incidental captures in British Columbia included marten, Canada lynx, and cougar.

Capture Histories, Spatial Use, and Movements of Wolverines: Five of our 14 study animals have been captured and monitored using satellite/VHF collars during multiple years (Table 3). Although the remaining wolverines have only been monitored during a single year, periodic detections at remote-camera stations have provided valuable information on the welfare and general location of those wolverines. To delineate wolverine activity areas (Table 4, Figure 4), we calculated 100% convex polygons using all location data in Argos accuracy-classes 1−3. Note that an activity area does not represent a home-range estimate; the estimation of home ranges requires careful data screening and more rigorous analytical procedures. Data on the areal extent of wolverine activity areas are presented here solely to provide a general idea of spatial use by our study animals.

Future Research: This past winter (2014/15) was our final year of trapping and, although we are still monitoring the movements of 1 male wolverine, we are transitioning from the data collection phase of the project to data analyses and publication of final results. During the course of our 10-year study, we live-captured and monitored the movements of 14 different wolverines (7 males and 7 females) and identified 2 additional wolverines (1 male and 1 female) via genetic analyses of scat or hair collected at camera stations. Working with other partners who are conducting camera surveys for wolverine and other forest carnivores, including the Woodland Park Zoo, various Forest Service Ranger Districts, the Washington Department of Fish and Wildlife and Conservation Northwest volunteers, we hope to continue gathering additional genetic samples from wolverines in the North Cascades Ecosystem and in neighboring regions to investigate the connectivity of wolverine populations in this portion of their range. In 2016, we will begin the analyses of telemetry location data to investigate the size and distribution of wolverine home ranges and the effectiveness of several competing habitat models (including the bioclimatic envelope model) for delineating wolverine habitat in the North Cascades Ecosystem.

2. **May 2012 Project Update** http://wolverinefoundation.org/wp-content/uploads/2011/02/ncws_update_may2012.pdf

Introduction: Greetings once again from the North Cascades Wolverine project in British Columbia and Washington. In our last update (March 9, 2012), we had live-captured 5 wolverines since the beginning of the year and attached satellite radio-collars to 4: 3 females (Mallory, Kendyl, and Xena) and 1 male (Rocky). Our live-trapping season continued until the end of March (British Columbia) and the beginning of April (Washington), but we did not capture any additional wolverines. Because of the heavy late-winter snows in March, many of our live traps were closed for extended periods due to high avalanche conditions or access issues. Regardless, we captured more wolverines this year than in any other year since the beginning of the study in 2006. This year also marks another first – we now have evidence that reproduction is occurring in our study population and we have found the first wolverine reproductive dens ever documented for the state of Washington.

3. **Winter 2011-2012 Update** http://wolverinefoundation.org/wp-content/uploads/2011/02/ncws_win2012update.pdf

Excerpts: Successes to-Date – Run-pole Camera Stations: Our first success this winter was in early December when Cliff Nietvelt (biologist with the BC Ministry of Forests, Lands, and Natural Resource Operations) obtained multiple photographs of a new wolverine at the Sumallo Grove run-pole camera station off of Highway 3 in British Columbia (top right). The throat and chest blazes clearly indicate that this is not one of our previously captured study animals.

In Washington, we detected Rocky (a male that we first captured and collared in 2006) at the Slate Creek run-pole camera station in early February (center right). We were able to make a positive identification based on his throat and chest blazes and the fact that he was still wearing the satellite collar that we fitted him with last winter.

Successes to-Date – Wolverine Captures: Thus far, we have captured 5 individual wolverines: 2 new wolverines and 3 previously captured study animals. This is the most wolverines we have captured in any given year, and brings our total number of individuals captured since the beginning of the study in 2006 to 10.

Mallory (an adult female first captured in 2011) was captured on 6 February at the Easy Pass trap in Washington. At the same time, a new wolverine was captured at the Bridge Creek trap (bottom right). We believe this wolverine was a male, but the immobilization drugs we administered were not effective on him. Thus, we collected some hair for genetic analysis and then released him without a satellite collar. We hope to recapture this individual soon, at which time we will use a different combination of immobilization drugs.

On February 18, we captured Xena (an adult female first captured in 2007) at the Twisp River trap in Washington (right). Although we detected Xena at a run-pole camera station in 2010, this is the first time we have recaptured her since 2007. Two days later on February 20, we captured Rocky at the Easy Pass trap. Rocky has now been captured during 5 different years (2006, 2008, 2010, 2011, and 2012) and is at least 8 years old.

Our most recent success was a new young female (Kendyl) captured on Leap Day, February 29, at the Memaloose trap in British Columbia.

All of the wolverines we have captured this year appear to be in excellent health: females were 9.5-9.9 kg (21-22 lb) and Rocky was 14.7 kg (32 lb). We outfitted 4 of the wolverines (all but the 1 captured at Bridge Creek) with satellite collars that will allow us to track their movements for the next 8 months.

4. **Wolverine Distribution and Ecology in the North Cascades Ecosystem – 2011 Annual Report.** Aubry, K., Rohrer, J., Raley, C.M., Lofroth, E.C., & Fitkin, S. (2011) U.S. Forest Service, British Columbia Ministry of Environment, and Washington Department of Fish and Wildlife http://wolverinefoundation.org/wp-content/uploads/2011/02/ncws_2011annual_rept.pdf

Results: *Trapping*—In Washington, we operated 2 traps during the pilot study (winter 2005/06), 4 traps during year 1 (winter 2006/07), 5 traps during year 2 (winter 2007/08), 11 traps during year 3 (winter 2008/09), 10 traps during year 4 (winter 2009/10), and 12 traps during year 5 (winter 2010/11) for a total of 2,694 trap nights. The number of trap nights for several of the traps was lower in year 5 (winter 2010/11) due to several periods of high to extreme avalanche danger (Table 2). We had to close the Hart's Pass and Rattlesnake traps on 3 occasions due to forecasted avalanche danger, and the Easy Pass trap was only in operation for 4 days due to avalanche activity that made the site inaccessible. To date in Washington, we have captured and radio-collared 8 different wolverines on 14 occasions during 6 winter field seasons (Table 2). Non-target species captured included Canada lynx, marten, and bobcat.

In British Columbia during the winter of 2008/09 (year 3), we operated most of the 10 livetraps for 17-20 nights between 13 January and 26 March. The only exception was the Sunshine Valley trap, which we closed after 4 nights due to high levels of human activity in the vicinity (we moved this trap to a better location in year 4). We did not capture any wolverines in British Columbia during year 3; incidental captures included marten and cougar. During the winter of 2009/10 (year 4), we operated 12 livetraps from 7 January to March 22 for a total of 472 trapnights. We captured 2 adult wolverines: Rocky on February 26 and Melanie, on March 22. Non-target species captured included Canada lynx and marten. During the winter of 2010/11 (year 5), we operated livetraps for varying number of days from 12 January to 5 April, but we did not capture any wolverines. Incidental captures included Canada lynx and marten.

Camera Stations—in year 4 (2009/10) in Washington, we obtained photographs of 3 individual wolverines on 9 occasions (Table 5). We obtained photographs of Rocky at the Bridge Creek station on February 21, 2010 and at the Slate Creek station on March 7 and 8, 2010. We obtained photographs of Xena at the Easy Pass station on February 15, March 18, 23, 24, and 31, and April 10, 2010 (Appendix, Photo 5). We obtained photographs of a wolverine new to this study at the Easy Pass station on March 23, 24, and 31. On March 23 there was a 29-minute separation between the photographs of the new wolverine and the photographs of Xena. On March 24 the separation between the 2 was 53 minutes and on March 31 it was about 185 minutes. It seems likely that these 2 wolverines were travelling together on those days. Subsequently, the new individual was live-captured in 2011 and named “Mallory”. During year 5 (winter 2010/11) we obtained photographs of Rocky at the Bridge Creek station on March 31, 2011, at the Easy Pass trap on March 28, April 7, April 27, and May 3, 2011, and at the Hart’s Pass trap on May 1, 2011. We obtained photographs of Mallory at the Easy Pass trap on April 27, 2011 (Appendix, Photo 9), and we obtained 1 photograph of Mattie at the Bridge Creek station on April 30, 2011. We obtained photographs of an unmarked wolverine at the Twisp Pass trap on May 8, 2011 (Appendix, Photo 10). Non-target species photographed included marten, lynx, black bear, coyote, mule deer, red squirrel, Stellar’s jays, Clark’s nutcrackers, and gray jays.

In British Columbia, we operated 9 run-pole camera stations during year 4 (2009/10) and detected Melanie on multiple days in February, March, and April 2010 at both the Memaloose and Cambie camera stations. We also detected Rocky on multiple days in February and April at these same 2 camera stations (Appendix, Photo 3). Camera detections of non-target species included marten, ermine, grizzly bear, black bear, cougar, bobcat, and spotted skunk. We did not detect any wolverines at run-pole camera stations in British Columbia during year 5 (2010/11); non-target species included black bear, Canada lynx, cougar, marten, deer, and moose.

Backcountry Snow-tracking Routes—In year 4 (winter 2009/10), we established 2 backcountry snowtracking routes in Washington to backtrack wolverines to obtain DNA samples (scat or hair; Ulizio et al. 2006) in areas that were too remote for trapping. We made a 3-day scouting trip into the Spanish Camp area of the Pasayten Wilderness from February 10-12. During this trip we followed 1 putative wolverine track and collected 2 scat samples, but the quality of the DNA from these samples was not sufficient to determine species. We completed a second trip into the Spanish Camp area from February 18-22 during which we followed 1 putative wolverine track for a short distance, but collected no samples. Finally, we completed a 4-day trip in the Sawtooth area from March 18-21, but we found no putative wolverine tracks and collected no samples. No back-country snow-tracking routes were attempted in year 5 (winter 2010/11).

5. **Distribution and Ecology of Wolverines in the North Cascades: Pilot Project – Year 2 Year-End Status Report.** Aubry, K., Raley, C., & Roher, J., (2007) U.S. Forest Service, Methow Valley Ranger District, Okanogan-Wenatchee National Forests.

Abstract: During the winter of 2006/07, we operated 4 log cabin-style livetraps for wolverines in the northwestern portion of the Methow Valley Ranger District in the Cascade Range of north-central Washington. We opened traps for varying time periods from January 9 to March 30, for a total of 180 trap-nights. We captured 3 different wolverines on 5 occasions, 2 of them twice and 1 once. We trapped one a third time, but he escaped. We fitted all 3 wolverines with radio-collars containing both satellite (Argos) and VHF transmitters. A young female (Xena) used an area about 760 mi2, based on 120 high-quality satellite locations (Argos location classes 1–3). A young male (Chewbacca) used an area of about 730 mi2, based on 80 high-quality locations. Xena and Chewbacca’s activity areas overlapped by about 90%. We recaptured Melanie this year, a young female we originally captured in February 2006. As of last year, she had not bred, but she was pregnant this year. Based on 130 high-quality locations, she used an area of approximately 560 mi2. Due to logistical constraints and problems encountered during aerial telemetry, we were unable to locate her natal den, or even verify that she had successfully reproduced. A preliminary analysis of elevational use by our 3 study animals indicated that elevations <4,400 ft were used less than expected, elevations 5,901–7,000 ft more than expected, and other elevation zones (4,401–5,900 ft and >7,400) at levels comparable to availability, suggesting a preference for relatively high-elevation habitats near treeline. In April 2007, we obtained a remote-camera photograph of Thor, a young male we originally captured in April 2006, near the Hart’s Pass trap. We suspect these 4 animals represent

2 mated pairs, because there was almost complete overlap of Chewbacca and Xena's activity areas and, although location data on Thor were limited, Melanie's activity area this winter completely encompassed Thor's activity area from last winter. Future research will involve the continuation of trapping and telemetry efforts, including the construction of 2 additional live-traps along the southern boundary of the Pasayten Wilderness, and field trials using GPS radio-collars in an effort to improve our ability to locate the natal and maternal dens of reproductive females.

Introduction: The wolverine (Gulo gulo) is one of the rarest mammals in North America, and the least known of large carnivores (Banci 1994). It is considered a sensitive species in the Pacific Northwest Region by the U.S. Forest Service, and a candidate species for listing as threatened or endangered by the state of Washington. The northern Cascade Range in Washington represents the southernmost extent of the current range of wolverines along the Pacific coast of North America (Aubry et al. 2007). Wolverines have never been studied in the field in this region, due partly to their low densities and extremely limited access during all periods of the year into the unroaded wilderness areas where they occur. Recent research on wolverines in the Rocky Mountains of British Columbia (Krebs et al. 2007) and the United States (Copeland 1996, Copeland et al. 2007, Squires et al. 2007) indicates that wolverines are wide-ranging, inhabit remote areas near timberline, and are sensitive to human disturbance at natal and maternal den sites. Winter recreation activities are widespread in the North Cascades and often occur in suitable wolverine denning habitat. Such activities may adversely affect wolverine populations or their preferred habitats.

Results: We captured 2 new wolverines, recaptured the juvenile female from last year, and documented the first known reproductive event for wolverines in Washington state. We captured wolverines 6 times in 180 trapnights for a capture rate of 1 wolverine per 30 trapnights, which is higher than the capture rate reported by Copeland (1996) in Idaho (1 wolverine per 47 trapnights). We were unable to re-capture the sub-adult male from last year, but that was probably due to our inability to maintain the Hart's Pass trap throughout the winter. All 3 of our new-design radio-collars remained on our wolverines throughout the winter, and generated 80-130 high-quality locations for each study animal during a 5-6 month period.

With these data, we were able to delineate activity areas for 3 wolverines, which indicate that Chewbacca and Xena, and probably Thor and Melanie, represent reproductive pairs (Figure 5). Although we do not know the fate of Melanie's offspring, we have documented that reproduction is occurring among Washington wolverines. Furthermore, during the past 2 winters, the activity areas for all 4 of our study animals were located primarily in Washington, demonstrating there is a resident population of wolverines in the state. Clearly, recent verifiable wolverine occurrence records in Washington did not simply represent Canadian wolverines that occasionally wander into Washington; rather, our results provide support for the current range of wolverines described by Aubry et al. (2007). However, the extent and location of the activity areas we delineated suggest that a relatively small number of wolverines may be capable of establishing home ranges within the state. The conservation of wolverines in Washington will depend on reliable knowledge of their distribution, population status, and habitat relations. This knowledge can only be gained by long-term field research; thus, it is essential to continue this research and find ways to expand the scope of our activities beyond the boundaries of our current study area.

Wolverine Monitoring for the Juneau Access Improvement Project – Berners Bay, Alaska

1. **Wolverine Monitoring for the Juneau Access Improvements Project – Wildlife Research Annual Progress Report.** Lewis, S.B., Flynn, R.W., and Barten, N.L. (2009) Alaska Department of Fish and Game, Division of Wildlife Conservation http://wolverinefoundation.org/wp-content/uploads/2011/02/BBAKProgress2009.pdf

Results and Discussion: Trap Placement and Construction: We constructed traps during late January and February 2008. We used a helicopter to sling trap material and built them on site (Fig. 3). We constructed these 8 traps in late January and February. During 2009, we used the same trap sites and reused most of the existing traps. Any traps not used will either be deconstructed and moved or destroyed on site.

Capture and Handling: *2008.*—From January to April 2008, we captured 4 individual wolverines (2 males and 2 females) 9 times during 701 trap nights resulting in a capture rate of 1.28 captures/100 trap-nights (Tables 1, 2). We had a capture rate for individual wolverines of 0.57 individual captures/100 trap-nights. All wolverines were captured in log or modified log box traps; no animals were captured in the portable plastic traps. All captures took place away from the beach edge of Berners Bay (Fig. 3). We anesthetized wolverines each time they were caught in our traps, and we collared each wolverine upon initial capture. Upon recapture, we downloaded GPS data from the collars for wolverines that retained them (M1 twice, F1 once) and deployed a new collar on wolverines that had dropped their original collar (F1 and F2; Table 2). Male wolverines weighted 14 – 15 kg and females weighted 8 – 9 kg.

Wolverines escaped from traps 2 times because of a malfunction in the bait attachment. A modified carbineer was used to connect the trigger wire to the wire surrounding the bait. In both cases, the animal was able to free the bait from this carbineer without triggering the trap and escape with the bait. After this occurred, all carabineers were removed and replaced with a locking connector that could not be unlatched by an animal. Non-target species captured included several martens and a domestic dog (*Canis familiaris*) in 2008 (Table 1). In addition, brown and black bears tripped traps, but did not get caught or were able to escape (identified by tracks at site). Two traps were partially destroyed by bears on the last day of trapping.

2009.—From January to February 2009, we captured 7 individual wolverines (5 males and 2 females) 8 times during 237 trap nights resulting in a capture rate of 2.28 captures/100 trap-nights (Tables 1, 3). We had a capture rate for individual wolverines of 2.95 individual captures/100 trap-nights. All wolverines were captured in log or modified log box traps. All captures took place away from the beach edge of Berners Bay (Fig. 3).

We anesthetized and collared each wolverine upon initial capture. One recaptured wolverine was not anesthetized on its second capture because it was only 1 week after the collar was deployed. This animal was released immediately after identifying it. Male wolverines weighted 13 – 14 kg and females weighted 10 – 11 kg. During 2009, non-target species captured included marten and a red fox (*Vulpes vulpes*; Table 1).

Monitoring: *2008* — Wolverine M1 was collared originally on 3/21/2008. He was recaptured on 3/29/2008 and retained his collar. We downloaded his collar at that time. He was recaptured a third time on 4/22/2008. He still had his collar, and we downloaded it and replaced the battery. M1's collar did not release on 10/7/2008 as scheduled. We were able to subsequently recapture this animal in 2009 to remove this collar.

Wolverine F1 was captured and collared on 4/15/2008. She was captured again on 4/20/2008 and we downloaded her collar. On 4/29/2008, F1 was captured a third time, but had lost her original collar and was given a new collar. On 4/30/2008, F1 dropped her second collar. On 5/3/2008, we attempted to collect both of F1's dropped collars. We found her second collar in a small cave formed by snow drifting over a large rock on a steep slope (Fig. 4). There were signs of porcupine roosting in the cave. The collar was found wedged between the rock and snow (Figure 4). We located F1's first collar in a band of cliffs but determined that it was in a deep cleft in the cliffs and was unreachable. F1's status at this time is unknown.

Wolverine F2 was first captured and collared on 4/18/2008 (Table 2). She was recaptured on 4/28/08 without that collar and was given a new collar at that time. She was last located on 6/25/2008, but has not been heard since that flight. Her first collar was located on 6/25/2008, but was not recovered before winter snows made it inaccessible. Subsequently this collar stopped transmitting a VHF beacon and therefore, we were unable to recover it. Her second collar was retrieved and downloaded on 9/11/2008. F2's status at this time is unknown.

Wolverine M2 was captured and collared on 4/22/2008 (Table 2). He has not been located since his capture despite several attempts to listen for his collar throughout the bay. At this time, we presume that either this animal dispersed from the study area or that the collar failed.

2009 — We recaptured wolverine M1 on 2/22/2009. We had documented him on 2 occasions near one trap using a remotely triggered camera. He still was wearing his collar from 2008 which we removed. We collared him with a new GPS collar upon recapture. He has been located several times, but his collar did not release. It appears that the collar is no longer transmitting a VHF signal and is lost.
We captured M3 on 1/27/2009 and collared him with a remotely-downloadable collar. We subsequently recaptured him on 2/8/2009, but released him without anesthetizing him. We have remotely downloaded his collar on several occasions and have most of the GPS locations from it. His collar did not release on the scheduled date, and we will need to recapture him to retrieve it.

We captured M4 on 2/11/2009 and collared him with a remotely-downloadable collar. We remotely downloaded his collar twice and have data up to 4/26/2009. Since that time, we have failed to locate his collar causing us to fear he dispersed or that his collar failed.

We captured M5 on 2/18/2009 and collared him with a remotely-downloadable collar. He slipped his collar on 3/22/2009. We recovered it on 9/29/2009 in an avalanche chute in the upper East Fork of Lace River (Fig. 5).

We captured M6 on 2/22/2009 and collared him with a store-on-board GPS collar. He was subsequently located on several occasions from the air, but he has not been located since before his collar was scheduled to release. He has either dispersed from the area or the collar has failed.

We captured wolverine F3 on 2/11/2009 and collared her with a store-on-board GPS collar. She was located from the air on several occasions, but has not been located since before her collar was scheduled to release. She has either dispersed from the area or the collar has failed.

We captured wolverine F4 on 2/14/2009 and collared her with a store-on-board GPS collar. She was located from the air on several occasions, but has not been located since before her collar was scheduled to release. She has either dispersed from the area or the collar has failed.

GPS Location Data: We downloaded collars 3 times from captured animals (M1 and F1; Table 2). We have recovered and downloaded 2 collars that animals dropped prematurely (F1 and F2; Table 2). Four collars remain in the field; 2 still on animals (M1 and M2), 1 yet to be retrieved (F2's first) and 1 that is irretrievable (F1's first).

We experimented with different fix schedules and search times in an attempt to maximize the time over which the collar would collect locations while minimizing the length of time between fixes (i.e., the fix rate). The initial schedule on M1 yielded a 12% fix success (20 fixes over 171 attempts; 70 sec max time) over 8 days (3/21 – 3/29). The second schedule on M1 yielded a 19% fix success (105 fixes over 549 attempts; 120 sec max time) over 24 days (3/29 – 4/22). F1's collar yielded a 36% fix success (39 fixes over 108 attempts; 120 sec max time). F1's collar 2nd fix success was 38% (35 fixes over 93 attempts;

120 sec search time). F2's 2nd collar yielded a 31% fix success (88 fixes over 283 attempts; 120 sec search time). Once we retrieve the remaining collars, we will determine which schedule met our needs and will use that for animals collared this coming field season.

Movements: Based on GPS location data from 1 male and 2 female collars, we calculated a 100% minimum convex polygon for each animal (Fig. 5). During 3/21/2008 – 5/2/2008, M1's home range area was 263 km2. During this time, he made repeated circuits of his home range, regularly covering the approximately 26 km length of this area in a day or two and crossing the approximately 1500 m ridge that runs the length of this area on several occasions (Fig. 5). Many of his locations were in habitat used by wintering mountain goats (White et al. 2007; K. White, pers. comm.). F1's collars were only worn for 8 days, during which she traveled over an area of 42 km2 (Fig. 5). During this time, she stayed in the valley bottoms mostly, never climbing higher than 800 m. During 4/28/2008 – 5/10/2008, F2's home range area was 65 km2. She spent most time on the mountain range between the Berners and Lace Rivers, with 1 foray across the Berners River valley to investigate a mountain goat carcass (collared mountain goat that died over the winter, K. White, pers. comm.). During the 2 weeks she wore her collar, she covered this area 3 times, including crossing the 1100 m ridge on several occasions.

Food Habits: We collected hair and blood sample from 4 wolverine live-captured during this study. In addition, we collected 6 samples from wolverines lethally trapped in the Berners Bay area. We will collect samples from all captured and trapped wolverines from Berners Bay this winter and send those in for stable isotope analysis to examine their diet.

2. **Wolverine Population Ecology in Berners Bay, Alaska – Wildlife Research Annual Progress Report.** Lewis, S.B., Flynn, R.W., and Barten, N.L. (2008) Alaska Department of Fish and Game, Division of Wildlife Conservation http://wolverinefoundation.org/wp-content/uploads/2011/02/BBAKProgress2008.pdf

Results and Discussion: *Trap Placement and Construction:* We began trap construction in January. We built 1 prototype trap near the end of the existing road system. Later in January, parts for 8 traps were slung to preselected sites around Berners Bay (Figure 3). We constructed these 8 traps in late January and February. We slung and built 2 additional traps in April and experimented with 2 portable, plastic traps in late March (Table 1).

Based on last year's trap results, we plan to reuse most of the existing traps. Any traps we do not use will either be deconstructed and moved or destroyed on site.

Capture and Handling: From January to April 2008, we captured 4 individual wolverines (2 males and 2 females) 9 times during 701 trap nights resulting in a capture rate of 1.28 captures/100 trap-nights (Tables 1, 2). We had a capture rate for individual wolverines of 0.57 individual captures/100 trap-nights. All wolverines were captured in log or modified log box traps; no animals were captured in the portable plastic traps. All captures took place away from the beach edge of Berners Bay (Figure 3).

We anesthetized wolverines each time they were caught in our traps. We collared each wolverine upon initial capture. Upon recapture, we downloaded GPS collars for wolverines that retained them (M1 twice, F1 once) and deployed a new collar on wolverines that had dropped their original collar (F1 and F2; Table 2). Male wolverines weighted 14 – 15 kg and females weighted 8 – 9 kg.

Wolverines escaped from traps 2 times because of a malfunction in the bait attachment. A modified carbineer was used to connect the trigger wire to the wire surrounding the bait. In both cases, the animal was able to free the bait from this carbineer without triggering the trap and escape with the bait. After this occurred, all carabineers were removed and replaced with a locking connector that could not be unlatched by an animal.

Non-target species captured included American marten (*Martes americana*) and a domestic dog (*Canis familiaris*; Table 1). In addition, brown and black bears tripped traps but did not get caught or were able to escape (identified by tracks at site). Two traps were partially destroyed by bears on the last day of trapping; the traps will be reconstructed for reuse.

Monitoring: Wolverine M1 was collared originally on 3/21/2008. He was recaptured on 3/29/2008 and retained his collar. We downloaded his collar at that time. He was recaptured a third time on 4/22/08. He still had his collar and we downloaded it and replaced the battery. On 6/25/2008 his collar was located from the air in 'recovery' mode, implying that it had been dropped and that the GPS battery was dead. However, upon attempting to retrieve this collar we learned that he was still wearing it. It is set to come off on 10/7/08 and will be located and retrieved after that.

Wolverine F1 was captured and collared on 4/15/2008. She was captured again on 4/20/2008 and her collar was downloaded. On 4/29/2008, F1 was captured a third time but had lost her original collar and was given a new collar. On 4/30/2008, F1 dropped her second collar. On 5/3/2008, we attempted to collect both of F1's dropped collars. We found her second collar in a small cave formed by snow drifting over a large rock on a steep slope (Figure 4). There were signs of porcupine roosting in the cave. The collar was found wedged between the rock and snow (Figure 4). We located F1's first collar in a band of cliffs but determined that it was in a deep cleft in the cliffs and was unreachable at the time. F1's status at this time is unknown.

Wolverine F2 was first captured and collared on 4/18/2008 (Table 2). She was recaptured on 4/28/08 without that collar and was given a new collar at that time. She was last located on 6/25/2008 but has not been heard since that flight. Her first collar was located on 6/25/2008 but had not been recovered to date because of its remote location and difficult weather. Her second collar was retrieved and downloaded on 9/11/2008. F2's status at this time is unknown.

Wolverine M2 was captured and collared on 4/22/2008 (Table 2). He has not been located since his capture despite several attempts to listen for his collar throughout the bay. We will continue to search for him and will conduct a thorough aerial search once his collar releases on 10/7/2008.

GPS Location Data: We downloaded collars 3 times from captured animals (M1 and F1; Table 2). We have recovered and downloaded 2 collars that animals dropped prematurely (F1 and F2; Table 2). Four collars remain in the field; 2 still on animals (M1 and M2), 1 yet to be retrieved (F2's first) and 1 that is irretrievable (F1's first).

We programmed collars with different fix rates to attempt to optimize the number of points acquired while maximizing battery life. The initial schedule on M1 yielded a 12% fix rate (20 fixes over 171 attempts; 70 sec max time) over 8 days (3/21 – 3/29). The second schedule on M1 yielded a 19% fix rate (105 fixes over 549 attempts; 120 sec max time) over 24 days (3/29 – 4/22). F1's collar yielded a 36% fix rate (39 fixes over 108 attempts; 120 sec max time). F1's collar 2nd fix rate was 38% (35 fixes over 93 attempts; 120 sec search time). F2's 2nd collar yielded a 31% fix rate (88 fixes over 283 attempts; 120 sec search time). Once we retrieve the remaining collars, we will determine which fix rate met our needs and will use that for animals collared his coming field season.

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F1's collars were only worn for 8 days, during which she traveled over an area of 42 km2 (Figure 5). During this time, she stayed in the valley bottoms mostly, never climbing higher than 800 m.

During 4/28/2008 – 5/10/2008, F2's home range area was 65 km2. She spent most time on the mountain range between the Berners and Lace Rivers, with 1 foray across the Berners River valley to investigate a mountain goat carcass (collared mountain goat that died over the winter, K. White, pers. comm.). During the 2 weeks she wore her collar, she covered this area 3 times, including crossing the 1100 m ridge on several occasions.

Food Habits: We collected hair and blood sample from 4 wolverine live-captured during this study. In addition, we collected 6 samples from wolverines lethally trapped in the Berners Bay area. We will collect samples from all captured and trapped wolverines from Berners Bay this winter and send those in for stable isotope analysis examine their diet.

3. **Wolverine Population Ecology in Berners Bay, Alaska – Wildlife Research Study Plan.** Lewis, S.B., Flynn, R.W., and Barten, N.L. (2007) Alaska Department of Fish and Game, Division of Wildlife Conservation http://wolverinefoundation.org/wp-content/uploads/2011/02/BBAKStudyPlan.pdf

<u>Introduction:</u> This report provides a summary of planned activities for the field season from December 2007 to June 2008.

Background: The wolverine (*Gulo gulo*) is one of the rarest and least-known carnivores in North America (Banci 1994, Ruggiero et al. 2007). Wolverines occur at low densities and tend to be found in areas removed from human influence (Banci 1994, Aubry et al. 2007). Because of this, relatively little was known about wolverine ecology until recently (Banci 1994, Squires et al. 2007). Research has shown that wolverines are susceptible to human disturbance (Krebs et al. 2007), that suitable denning habitat is a critical habitat component for wolverine population persistence (Magoun and Copeland 1998), and that harvest is an additive mortality that can significantly affect population demographics and cause local extirpation of wolverine populations (Hornocker and Hash 1981, Krebs et al. 2004, Squires et al. 2007).

Wolverines are managed as a commercial furbearer in Alaska for which trapping and hunting is allowed. Based on sealing records from southeast Alaska, 19 wolverines (on average) were harvested in Units 1 – 4 over the last 12 years; 42% of these were taken from Units 1C and 1D in northern southeast Alaska. Over that time, 0-4 wolverines were harvested in the Berners Bay area annually. Although sealing provides managers with some useful information on each animal sealed (e.g., sex and general location of harvest) and general trend of harvest, it provides no information about the wolverine ecology or insight about current or future population levels.

In southeast Alaska, access during the winter trapping season is logistically challenging because of limited road access to wolverine habitats. Near Juneau Alaska, the Alaska Department of Transportation and Public Facilities (DOT) is planning to construct an all-season highway that will extend the existing highway from Juneau approximately 50 miles northwest. This road will pass through habitats occupied by wolverines and provide significantly increased access to these areas. Increased access to wolverine habitats, provided by this road, will significantly change human access to wolverines, and likely increase exploitation rates. In addition, this road could provide snow machine access to habitats used by female wolverines for denning and kit rearing (Magoun and Copeland 1998), potentially resulting in conflicts between female wolverines at their dens and recreational snow machine riders.

Knowledge of wolverine ecology and population dynamics is limited and field studies are needed to fill critical information gaps (Ruggiero et al. 2007). This is especially true in coastal areas like southeast Alaska (Magoun et al. 2007). Information on basic ecology, including home-range size and habitat use, movements and dispersal characteristics, and diet are needed to determine factors affecting wolverine abundance and ultimately to ensure sustainable populations (Krebs et al. 2004, Lafroth and Ott 2007). By learning the role and relative importance of these factors, we will be able to appropriately manage this species in a responsible manner per the Alaska Department of Fish and Game, Division of Wildlife Conservation's mission to "Conserve and enhance Alaska's wildlife and habitats and provide for a wide range of public uses and benefits".

Objectives: This research is designed to investigate the ecology of wolverines in the Berners Bay area of northern southeast Alaska. The specific objectives are as follows:

1) Determine spatial-use patterns (i.e., home range, movements) and habitat selection of wolverines in the Juneau Access study area;
2) Derive a wolverine population estimate for the Juneau Access study area, and;
3) Investigate wolverine food habits in the Juneau Access study area.

Wolverine Survey: Wallowa-Whitman National Forest, NE Oregon

1. **Monitoring Wolverines in Northeast Oregon: January 2011-December 2012 Final Report.** (2013) http://wolverinefoundation.org/wp-content/uploads/2013/03/Wallowa-Wolverine-Final-Report_2013.pdf

Discussion and Conclusions: *Deployment of Camera Stations* Winter: The best time to establish camera stations for winter camera trapping in the Wallowa Mountains is late October and early November before snow has accumulated to depths that make it difficult to transport camera station equipment and bait to high elevation sites. Hanging bait at camera stations earlier than late October may result in bait rotting before night temperatures fall below freezing. Deploying cameras in the fall has some drawbacks however. It is often difficult to judge how deep snow might accumulate at the station over winter, therefore, the run pole and camera must be mounted high enough to avoid being covered in snow. Choosing sites under large trees with closed canopies and in areas protected from wind will help with this problem but it may be necessary to use climbing equipment to construct the station at a height that will be above the snow surface throughout the winter. Moreover, wolverine movements increase in late winter and previous camera-trapping studies have shown that detectability of wolverines at camera stations is higher in late winter and spring (Royle et al. 2011). Therefore, camera stations established in the fall should be visited again, preferably by the end of January, to add bait and change memory cards and batteries to ensure that the station is functional during the critical late winter period. Ideally, camera stations should be checked monthly to be sure that no opportunity is lost to detect wolverines because of malfunctioning cameras or bait removed by other scavengers. As temperatures begin to warm in the spring months, it is necessary to visit camera stations more frequently when collecting hair for DNA because DNA quickly degrades in warm temperatures, especially when exposed to sun and moisture.

Although a wolverine was detected at 2 camera stations within 4 and 8 days, respectively, of station deployment (Table 2), the remaining camera stations with wolverine detections operated for a month or more, and 1 for as many as 185 days, before wolverines were detected at the stations. We recommend that camera stations should be deployed for at least 3 months, and preferably longer, to allow sufficient time for wolverines to find the stations. Camera stations deployed in the fall should be active over the entire winter, particularly February–April and including May if possible, to provide the best opportunity to detect wolverines.

Summer: We obtained useful information on scavengers using high elevation sites in summer, but we did not detect wolverines at summer camera stations even though some of the stations were ~1 mile from winter stations used by Stormy as late as the middle of June in 2012. Snow lingered so long in the spring and early summer in the ECW that we were not able to deploy cameras at high elevations until late July and early August in 2012, considerably shortening the period the summer camera stations were active before fall snowstorms necessitated removing the cameras. It would have been better to begin deployment in spring as soon as the danger of avalanches had subsided, but we had no prior knowledge of boulder scree fields that would provide the best sites for bait over the summer and most of the best sites at high elevations, including the sites we eventually used, were still covered with snow in May and June. To deploy summer camera stations earlier than July, specific locations for the stations would need to be chosen in the fall and marked so they can be relocated in the spring and the snow excavated down to a cavity in the boulders. Ideally, summer camera stations at high elevations should be run from May through October in the ECW. We recommend using only sites with boulder scree for summer camera stations because these were the only sites that prevented bears and coyotes from accessing the bait. Consideration must also be given to positioning cameras to take into account how the detection zones of cameras might change as the snow melts over summer.

Wolverine Detections at Camera Stations: Only 3 wolverines were detected in the study area in 2 years of camera trapping, despite the use of 43 functional camera stations and 6,205 active camera-station days over the 2 years, and only 1 wolverine (Stormy) was detected in the 2011-2012 season. We cannot conclude that there were no other wolverines residing in the ECW in 2011-2012, but the failure to detect additional animals suggests that there were very few wolverines, possibly only a single individual, in the second year. Certainly, within the small area in the central part of the ECW where the 3 wolverines were detected over the 2 years (Fig. 22), it is unlikely that any wolverine other than Stormy was present in 2011-2012 give n Stormy's detection history. Stormy was detected at 10 of 20 active camera stations within the central ECW in 2011-2012 and 6 of the stations where he was not detected were summer camera stations. Considering only camera stations active in the central ECW in winter 2011-2012, Stormy failed to visit only 4 of 14 stations. Because wolverines often follow each other to sources of food, it is unlikely that other wolverines, had they been present in the central ECW in 2011-2012, would have failed to find at least 1 of the winter camera stations used by Stormy that winter, especially since 3 of the 4 stations not visited by Stormy in 2011-2012 were visited by wolverines in 2010-2011 (Stormy, Zed, and an unidentified wolverine). Winter camera stations were distributed north and south of the central ECW where Stormy was located in both years of the study, but no wolverines were detected in these areas (Fig. 6). Camera stations in the home ranges of wolverines are not always visited by the resident wolverines (Magoun, personal observations), including Stormy in this study, so it is possible that wolverines were present in these areas but went undetected at the camera stations.

Wolverines can reach densities of 25/1000 mi2 (9.7/1000 km2; Royle et al. 2011) not including young of the year, but estimates of wolverine density at the southern periphery of their distribution in North America are much lower. For example, a density of 9.3/1000 mi2 (3.5/1000 km2; Inman et al. 2012b) is probably more typical in the western United States, particularly where wolverine habitat is fragmented into relatively small mountain ranges separated by low elevation valleys. Using this lower estimated density, we assume that the ECW, an area of 560 mi2, could support about 5 wolverines. Some suitable habitat lies outside the ECW to the south, and areas within the WWNF to the east of the ECW could contain portions of home ranges of wolverines occupying the ECW. Therefore, a reasonable estimate of the number of wolverines that could occupy the ECW and adjacent areas in the WWNF would be about 6 animals (not including young of the year). That we found only 1 resident wolverine in 2 years of camera surveys in and adjacent to the ECW suggests that either the habitat is insufficient to support a higher density or wolverines have not fully reoccupied the available habitat.

Results from other camera-trapping studies suggest that detectability of wolverines using cameras in our study area is considerably lower than for wolverine populations with reproductive females. In southeast Alaska, in an area of 965 mi2 where density was estimated at 25/1000 mi2 (9.7/1000 km2; Royle et al. 2011), 21 different wolverines were identified using 37 camera stations over a 165-day period during January–May, yielding an average detection rate of 0.57 individual wolverines per camera station. In western Montana, where density was estimated at 9.3/1000 mi2 (3.5/1000 km2; Inman et al. 2012b), a camera-trapping study identified 9 wolverines using 37 camera stations over a 61-day period (March−April), yielding an average detection rate of 0.24 wolverines per station (Robert Inman, personal communication). In our study in the first season, we detected an average of 0.19 wolverines per station (3 wolverines detected using 16 camera stations) but this dropped to 0.04 in the second year of the study, even though we had more camera stations (26) and a longer camera-trapping season (October−June). Even if the additional 2 wolverines (Iceman and Zed) had been detected on cameras in the second year, the average number of wolverines per station would only have been 0.12.

2. **Wallowa Wolverine Project: 2011-2012 Progress Report** (2012) Wallowa-Whitman National Forest http://wolverinefoundation.org/wp-content/uploads/2012/05/WWWS2012AprilUpdate.pdf

Summary: Field work began on 26 September 2011 and by the end of April 2012, we had established 26 camera stations in and adjacent to the Eagle Cap Wilderness in the Wallowa-Whitman National Forest (Table 1). Access to camera sites was on foot, horse, snowmobile, ATV, skis, and snowshoes. The 6 camera stations that had wolverine visits in late winter 2011 were reestablished this season. Ten of the stations were below 6000' elevation (4784'-5820'). The remaining stations were located between 6014' and 7373' elevation. Additional stations may be added in May or June, depending on travel conditions in the mountains. One station was removed (WCAM1) because of its proximity to where the wolverine Stormy was trapped in December to prevent habituation of the wolverine to this site.

Of the 26 established camera stations, 24 (92%) have been checked at least once (total=57 checks) and at these stations, there were 2,680 active camera days. One wolverine (Stormy; Fig.1-3) has been photographed at 7 stations, including 4 stations where he was photographed in 2011. No other wolverines have been photographed to date. Eighteen other species have been detected at the camera stations (Table 2). Marten have been detected at 21 of the 24 (88%) stations that have been checked so far, and marten hair was collected at many of these stations and submitted for DNA analysis.

We flew tracking flights on 6 days (Fig. 4), most in April, and have located wolverine tracks, or probable wolverine tracks, in 3 areas. Snow conditions and weather made aerial tracking problematic this season. Few calm clear days occurred before April and unseasonably warm weather in April caused rapid melting out of tracks even at high elevations.

Camera stations will be run through May and into June for stations at the higher elevations. If funding is available, we plan to run camera stations at high elevations near snowfields that last into late summer, especially in areas of the Eagle Cap Wilderness that were inaccessible during the winter. Few attempts have been made to use camera "traps" during summer to detect wolverines. We will test the effectiveness of summer camera trapping by deploying cameras within the area used by wolverine detected this winter.

3. **Monitoring Wolverines in Northeast Oregon – 2011 Final Report.** Magoun, A.J., Valkenburg, P., Long, C.D., and Long, J.K. (2011) The Wolverine Foundation http://wolverinefoundation.org/wp-content/uploads/2011/09/wwwp_final_pe.pdf

Conclusion Excerpts: *Camera Detection of Wolverines in the Wallowa Mountains:* Our cameras identified the first verified records in Oregon in nearly 20 years and the first ever in the Wallowa-Whitman National Forest. Even though female wolverines were not detected, the presence of 2 subadult males suggests that there could be a breeding population of wolverines in the study area. The DNA collected from one of the wolverines indicated that this wolverine is more closely related to individuals in Idaho than to wolverines in Washington. It is possible that this wolverine dispersed from Idaho across the Snake River and was not born in the study area. However, it seems unlikely that 3 wolverines would have dispersed from Idaho, all in late winter 2011 and found camera stations all within a relatively small area of the Eagle Cap Wilderness. It is more likely that there are resident wolverines in the Eagle Cap Wilderness. Another year of camera trapping is needed to determine if female wolverines are resident there.

Whether or not wolverines are resident within the study area, the presence of the wolverines we detected indicates that the Wallowa-Whitman National Forest and the Hells Canyon National Recreation Area, between the Eagle Cap Wilderness and the Snake River on the Idaho border, is potential dispersal habitat for wolverines moving from source habitat in Idaho and Montana to areas further west and north of our study area. The male wolverine that was recently detected in northern California could have dispersed from Idaho (Moriarity et al. 2009), possibly through the Wallowa-Whitman National Forest, or may have originated from within the Wallowa-Whitman National Forest. Periodic sightings of wolverines in the study area and in mountains west of the study area in recent years and the occasional verified record of wolverines in Oregon (Hiller 2001) suggest that occurrences of wolverines in Oregon may not represent extreme dispersal events (Aubry et al. 2007; Verts and Carraway 1998). Rather, we suggest that regularly-occurring dispersal events, and possibly even small breeding populations of wolverines, could exist in Oregon but remain undetected or unverified by criteria defined by Aubry et al. (2007). In fact, we suggest that the status of the wolverine in Oregon should receive further attention with additional camera surveys in the Blue Mountains, East Cascades, and West Cascades Ecoregions of Oregon (ODFW 2006) and in some of the more isolated mountainous areas outside these areas where there have been reports of wolverines (Hiller2011).

4. **Wolverine Survey: Wallowa-Whitman National Forest, NE Oregon – Study Plan** Long, C., Magoun, A., and Valkenburg, P. (2010) The Wolverine Foundation http://wolverinefoundation.org/wp-content/uploads/2011/02/wwws.pdf

Summary: A pilot study to survey for wolverines in the Wallowa-Whitman National Forest within and adjacent to the Eagle Cap Wilderness using proven non-invasive detection methods for wolverines. *Location of study:* The proposed study area is located within and adjacent to the 1,418-km2 Eagle Cap Wilderness (ECW) in the Wallowa-Whitman National Forest (WWNF) of northeastern Oregon, USA (Fig. 1). The ECW is comprised of montane forests at lower elevations and sub-alpine/alpine habitat with glacial cirques, perpetual snow/ice fields, and glaciers at higher elevation. Elevations range from 1,220 m to 3,027 m. No motorized travel is allowed in the ECW and access to the periphery of the ECW is limited to a series of unimproved USFS, county, and state roads.

Background: We believe the ECW and adjacent forest may contain suitable wolverine habitat and comprise an important linkage area between disjunct wolverine habitats in the Pacific Northwest; however, a resident population of wolverines has not been verified in the study area. At higher elevations, temperatures and snow cover are historically consistent with the hypothesized bioclimatic criteria for wolverine presence (Copeland et al. 2010) and, based on discussions with biologists familiar with the area, food resources appear to be adequate to support wolverines. Although 28 wolverine sightings have been reported in the WWNF (USFS Wallowa-Whitman National Forest data base), including 1 in 2008, no sighting or evidence of presence has been verified using criteria outlined by Aubry et al. 2007. Approximately 95 km to the east of the ECW, a resident reproducing wolverine population is present in the Payette National Forest of central Idaho (USFS RMRS 2010; unpublished data). During aerial track surveys in 1998 (Edelmann et al. 1999) and again in 2009 (USFS RMRS; unpublished data), at least 1 set of wolverine tracks was detected in the Seven Devils Mountains of central Idaho, approximately 45 km east of the ECW. Viability of a potential "Seven Devils" wolverine population is unknown. Photographs and/or DNA from wolverines in the WWNF would verify the presence of this species (Aubry et al. 2007) and could provide evidence of a breeding population if lactating females are detected (Magoun, unpublished data), or if specific familial (parent/offspring) relationships from DNA are determined. Even if a resident population of wolverines is not verified during this study, long-term monitoring for wolverines in the WWNF and ECW may be desirable for assessing habitat suitability for wolverines in the WWNF and the role the study area plays in providing dispersal habitat for wolverines in the Northwestern Forested Mountains ecoregion, a Level 1 ecoregion designated by the United States Environmental Protection Agency (http://www.epa.gov/wed/pages/ecoregions.htm). For example; the study area may have served as a dispersal route for a wolverine recently documented in northern California, because mitochondrial DNA indicated that this wolverine probably originated from along the western edge of the Rocky Mountains and could even have originated from within the Wallowas or Seven Devils Mountains, but DNA samples from wolverines have not been collected from this area (Moriarty et al. 2009). Despite their unknown status in Oregon, the wolverine is listed as "Threatened" by the Oregon Department of Fish and Wildlife (ODFW) and ODFW recognizes the need for monitoring as an essential element of successful implementation of the Oregon Conservation Strategy (ODFW 2006).

Objectives:

A. Use two independent, non-invasive detection methods to investigate the presence of wolverines in the Wallowa-Whitman National Forest within and adjacent to the ECW.
    1) Repeated aerial track surveys (≥3) for the presence of wolverine tracks in treeless portions of the ECW.
    2) Motion detection cameras and associated hair-snag devices to detect wolverines in the forested portions of the study area.

B. Make recommendations regarding future surveys and monitoring for wolverines in the WWNF and ECW.

Other Wolverine Research

1. **Distribution of Broadscale Habitat Relations of the Wolverine in the Contiguous United States.** Aubry, K., McKelvey, K. & Copeland, J. (2007) Journal of Wildlife Management 71(7):2147-2158) http://wolverinefoundation.org/wp-content/uploads/2011/02/aubrey_etal_2007_distribution.pdf

Abstract: Conservation of the wolverine (*Gulo gulo*) at the southern extent of its North American range requires reliable understandings of past and present distribution patterns and broad-scale habitat relations. We compiled 820 verifiable and documented records of wolverine occurrence (specimens, DNA detections, photos, and accounts of wolverines being killed or captured) in the contiguous United States from museums, the literature, and institutional archives. We spatially referenced 729 records with areal precision ≤1 township (93.2 km2) and temporal precision ≤10 years. Historical records (1827–1960) were located primarily in the western mountains and Great Lakes region. However, our data suggest that the historical distribution of wolverines in the Cascade Range and Sierra Nevada was disjunct, contradicting previous interpretations. Our results indicate that wolverine range in the contiguous United States had contracted substantially by the mid-1900s. Current records (1995–2005) are limited to north-central Washington, northern and central Idaho, western Montana, and northwestern Wyoming. We investigated potential relations between wolverines and alpine vegetation, cold temperatures, and spring snow cover by comparing the distribution of historical wolverine records with Kuchler's potential natural vegetation types, Holdridge's climatic life zones, and EASE snow-cover maps during the latter portion of the wolverine denning period (15 Apr–14 May). In the western mountains, historical wolverine records generally occurred in or near alpine vegetation and climatic conditions, especially at the limits of their

distribution in the Cascade Range, Sierra Nevada, and southern Rocky Mountains. However, the only habitat layer that fully accounted for historical distribution patterns was spring snow cover. Causal factors for the extirpation of wolverines from the southern portions of their range in the contiguous United States are unknown, but are likely related to high levels of human-caused mortality and low to nonexistent immigration rates.

2. **Historical Biogeography of the Wolverine in the United States.** McKelvey, K., Aubry, K., & Rivera, P.T. (2002) Proceedings from Defenders of Wildlife Conference on Carnivore Biology and Conservation. p. 64.

Abstract: We compiled current and historical records of wolverine (*Gulo gulo*) occurrence in the contiguous United States from published literature, museums, state wildlife agencies, federal resource management agencies and natural heritage databases. Records obtained were of varying degrees of reliability; they included many museum specimens, photos and first- hand accounts of wolverines being trapped (verified records), but were dominated numerically by visual observations of wolverines or their tracks (unverified records). Resulting biogeographic analyses, including assessments of the current and historical distribution of wolverines in the United States, and correlations between elevation and land-cover types varied substantially in accordance with the reliability of occurrence records included in the analyses. Specifically, the geographic distribution of wolverines based only on verified records is much more disjunct and isolated within high-elevation, boreal habitats than is depicted in published range maps. The distribution of verified records also suggests that wolverines have been absent for many years from California, Colorado and the Great Lakes states. We compare inferences resulting from various data sets and discuss the challenges and conservation implications of determining the current and historical ranges of rare and secretive species that have not been surveyed with reliable methods.

Wolves / Gray

1. **Effects of Winter Recreation on Gray Wolves.** (1999) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: A Literature Review and Assessment. Olliff, T., Legg, K. & Kaeding, B. Greater Yellowstone Coordinating Committee, Yellowstone National Park. pp. 31-35. http://www.nps.gov/yell/parkmgmt/upload/wildlifewint.pdf

Potential Effects: Conflicts could occur when routes groomed for snowmobiles bisect habitats used by wolves in the winter, affecting wolf movements and foraging patterns. Moreover, grooming of roads and trails may affect ungulate movements (Meagher 1993), and this may influence wolf movements as well. Areas of particular concern are ungulate concentration sites where winter-killed carcasses are available. These include both geothermally influenced and low-elevation sites. Wolf activity could be affected in ungroomed areas used by snowmobiles. Although areas of ungroomed snowmobile use typically occur at high elevations where wolves do not occupy winter habitats, there is potential for conflicts between wolves and recreationists if winter snowmobiling occurs on low-elevation or geothermally influenced ungulate winter range. Impacts would also occur if wolves were deliberately chased by recreationists on snowmobiles.
Management Guidelines: New groomed motorized routes should be located in areas that are not classified as ungulate winter range or important wolf habitat. Grooming and use of snowmobile roads and trails should end between March 15 and April 1, allowing wolves to use spring denning sites without harassment. Dispersed motorized use should not occur on or near ungulate winter range or on spring range after wolf denning begins, usually between March 15 and April 1.

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