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Snowmobile Best Management Practices for Forest Service Travel Planning: A Comprehensive Literature Review and Recommendations for Management – *Introduction to Snowmobile Management and Policy*

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ABSTRACT: Wintertime backcountry recreation, including snowmobiles, is a large and rapidly growing use on National Forest System lands. As the number of participants increase, so does the potential for conflict between motorized and non-motorized uses, as well as impacts to natural resources such as wildlife, water quality, soils, and vegetation. The USDA Forest Service has started travel analysis across forests in the snow-belt region, which will determine where motorized use is allowed, restricted and prohibited for decades to come. For planning to be effective, managers and conservationists must have access to the most recent data on the impacts of snowmobiles and need to be aware of successful management strategies for mitigating those impacts. The next four articles review the environmental and social impacts of winter motorized recreation and present a set of best management practices (BMPs). Article 1 provides context and describes the current state of management and policy governing snowmobiles. Article 2 reviews water quality, soils, and vegetation research and presents BMPs to reduce the impacts to these resources. Article 3 reviews research on the impact of snowmobiles on wildlife and presents BMPs to address those impacts. Article 4 reviews the growing conflict between non-motorized users and snowmobile users and presents BMPs to mitigate this conflict. Applying these BMPs will lead to a more socially and environmentally sustainable system of motorized and non-motorized routes and areas on National Forest lands.

Keywords: Travel planning, snowmobiles, best management practices, BMPs, winter recreational use conflict, wildlife, water quality, soils, vegetation, USDA Forest Service

INTRODUCTION

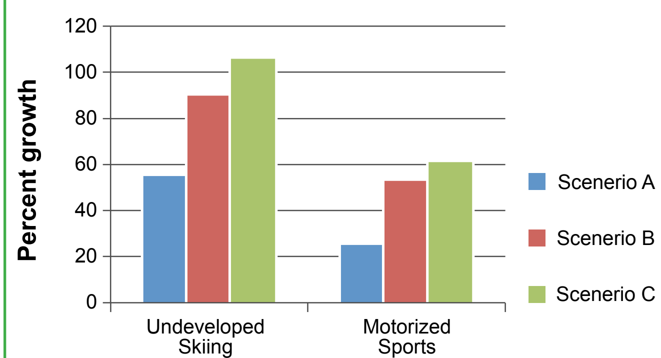
Winter backcountry recreation is a popular and steadily growing activity on USDA Forest Service (Forest Service) lands. Undeveloped skiing (including backcountry skiing, cross country skiing, and snowshoeing) is projected to be one of the top five fastest growing activities on Forest Service lands within 50 years (Figure 1). In one scenario, the number of participants in undeveloped skiing is predicted to double – reaching 16 million participants by 2060 (Cordell 2012). Motorized snow activities, including snowmobiling, are forecasted to grow as well, albeit at a slower rate. Overall, more than 20 million people participate in some form of backcountry winter recreation on National Forest lands each year (Cordell 2012).

Snowmobilers and skiers often seek out the same winter backcountry setting, looking for similar experiences such as solitude, fun, and the enjoyment of the natural beauty of the mountains. As motorized and non-motorized winter recreation grows on Forest Service lands, so does the potential for conflicts between the two user groups and impacts on natural resources. In terms of recreation opportunity, snowmobile use adversely impacts the recreation experience sought by many non-motorized users, while the reverse is rarely true. Motorized recreation will displace non-motorized users where use is heavy. This has occurred in numerous places. Where actual displacement does not occur, conflicts among users still arise from snowmobile use; the associated noise and fumes often creates annoyance for non-motorized users – especially if they are seeking quite solitude.

Additionally, advancements in technology and changes in use patterns of both user groups have increased the need for proactive management. In the early years, snowmobiles were relatively slow and limited to groomed trails; today's snowmobiles can go off-trail and up very steep slopes. "High marking" steep alpine bowls is now a popular riding technique, and modified motorcycles with a tread and ski allow riders to negotiate even heavily wooded areas. Backcountry skiers and snowboarders also have seen their sports evolve through technological changes in gear, making it easier for skiers and snowshoers to climb and descend mountains in the deepest of winter, thus accelerating the trend of increased user participation and demand.

These advancements and changes in use patterns have led to increased user conflicts and negative impacts on natural resources. Snowmobiles can impact wildlife, resulting in declines in animal health, fragmentation, and potential population declines (Gaines et al. 2003). Water quality, vegetation, and soils can also be greatly affected – especially in more sensitive alpine environments. Hundreds of research papers and monitoring reports have quantified these impacts and have been summarized in a number of recent literature reviews (e.g., Stokowski and LaPointe 2000, Gaines et al. 2003, Baker and Bithmann 2005, Davenport and Switalski 2006, Ouren et al. 2007, USDI NPS 2011, WWA 2014).

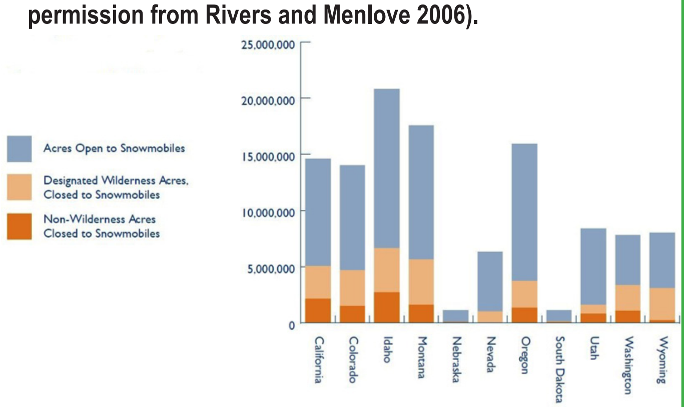
Figure 1: Percent growth in projected number of participants in undeveloped skiing and motorized snowsports on Forest Service lands in three model scenarios, 2008-2060 (adapted from Cordell 2012).



Snowmobile Management

In recent years, the Forest Service identified "unmanaged recreation" as one of the four threats to the health of National Forests (Bosworth 2003). On most forests, snowmobile activity was never formally planned or expected, but resulted from a default policy of allowing motorized use. This stance arose primarily due to the absence of a compelling reason to close or restrict motorized access, as it was already deemed self-limiting due to extreme terrain challenges and limitations of current technologies of the time. As a result, more than 70 percent or 81 million acres in the western snowbelt forests are open to potential snowmobile use (Rivers and Menlove 2006, Figure 2). While skiers (including cross country, backcountry, and snowshoers) outnumber snowmobiles on National Forest System lands (USDA FS 2014a), significantly more acreage and trail miles are available for winter motorized recreation (Rivers and Menlove 2006, Figure 2). Of the 30 percent or 35 million acres closed to snowmobiles, two-thirds are in designated Wilderness Areas where all motorized use is legally prohibited, but where human-powered winter recreation opportunities are often difficult or impossible to access. Furthermore, numerous existing trailheads are weighted towards snowmobile recreation. The legacy of this *unplanned* "allocation" is widespread *open* allocation for winter motorized use that is often not based on historical use patterns or any specific rationale. Furthermore, significant displacement of non-motorized users has occurred as snowmobiles expand their reach, aided by ever-increasing technological advancements (e.g., Stokowski and LaPointe 2000, Manning and Valliere 2001, Adams and McCool 2010). Addressing this allocation disparity is critical to addressing recreational use conflict (Adams and McCool 2010).

Figure 2: Acres open and closed to snowmobiles on National Forests in the western snowbelt region (reprinted with permission from Rivers and Menlove 2006).



Main Authorities Governing the Management of Snowmobiles in the National Forest System

In the early 1970s, management of snowmobiles and other motorized uses on public lands was inconsistent. However, after a series of ecological research findings and a rising need for conflict management, President Nixon signed Executive Order 11644 on February 8, 1972. This order charged federal land managers with developing and issuing regulations to manage off-road vehicles, including snowmobiles, specifically to *minimize* damage to natural resources and *minimize* conflicts between motorized and non-motorized communities. The Executive Order continues to be the primary legal authority guiding off-road vehicle designations on public lands.

Executive Order 11644

> Section 3. Zones of Use. (a) Each respective agency head shall develop and issue regulations and administrative instructions, within six months of the date of this order, to provide for administrative designation of the specific areas and trails on public lands on which the use of off-road vehicles may be permitted, and areas in which the use of off-road vehicles may not be permitted, and set a date by which such designation of all public lands shall be completed. Those regulations shall direct that the designation of such areas and trails will be based upon the protection of the resources of the public lands, promotion of the safety of all users of those lands, and minimization of conflicts among the various uses of those lands. The regulations shall further require that the designation of such areas and trails shall be in accordance with the following—
>
> (1) Areas and trails shall be located to minimize damage to soil, watershed, vegetation, or other resources of the public lands.
>
> (2) Areas and trails shall be located to minimize harassment of wildlife or significant disruption of wildlife habitats.
>
> (3) Areas and trails shall be located to minimize conflicts between off-road vehicle use and other existing or proposed recreational uses of the same or neighboring public lands, and to ensure the compatibility of such uses with existing conditions in populated areas, taking into account noise and other factors.
>
> (4) Areas and trails shall not be located in officially designated Wilderness Areas or Primitive Areas. Areas and trails shall be located in areas of the National Park system, Natural Areas, or National Wildlife Refuges and Game Ranges only if the respective agency head determines that off-road vehicle use in such locations will not adversely affect their natural, aesthetic, or scenic values.

In 1977, President Carter signed Executive Order 11989, which amended and strengthened EO 11644 by giving federal public land managers the authority to close a motorized route or area if current access "will cause or is causing considerable adverse effects" to natural resources:

Executive Order 11989

> Section 9. Special Protection of the Public Lands. (a) Notwithstanding the provisions of Section 3 of this Order, the respective agency head shall, whenever he determines that the use of off-road vehicles will cause or is causing considerable adverse effects on the soil, vegetation, wildlife, wildlife habitat or cultural or historic resources of particular areas or trails of the public lands, immediately close such areas or trails to the type of off-road vehicle causing such effects, until such time as he determines that such adverse effects have been eliminated and that measures have been implemented to prevent future recurrence.
>
> (b) Each respective agency head is authorized to adopt the policy that portions of the public lands within his jurisdiction shall be closed to use by off-road vehicles except those areas or trails which are suitable and specifically designated as open to such use pursuant to Section 3 of this Order.

Travel Management Rule (TMR)

Over the last few decades, impacts resulting from unmanaged off-road vehicle use and the growth of non-motorized backcountry recreation on National Forest System lands have led to a renewed effort to comply with the Executive Order direction. In 2005, the Forest Service promulgated the Travel Management Rule (TMR) to govern the management of summer and winter off-road vehicle systems. Subpart B of the TMR requires the Forest Service to have a designated summertime off-road vehicle system, while subpart C allows *but does not require* the Forest Service to designate a wintertime off-road vehicle system.

In 2013, a Federal court found that subpart C failed to comply with the direction in the Executive Order to designate a system of trails and areas that minimize impacts to natural resources and conflicts. In response, the Forest Service in 2014 issued a draft amendment to the TMR requiring the designation of roads, trails, and areas where over-snow vehicle (OSV) use is allowed, restricted, or prohibited. A final winter travel rule is expected in the near future. In the coming years, areas that receive enough snow to support winter recreation will be required to have a system of designated routes and areas for winter motorized use, providing opportunity for public input as they do so. The BMPs presented in the next three articles are designed specifically to aid in the process of OSV route and area designation, and to improve management and monitoring on Forest Service lands.

Best management practices (BMPs) for minimizing impacts from snowmobiles

Best management practices provide science-based criteria and standards that land managers follow in making and implementing decisions that affect natural resources and human uses. BMPS are usually developed for a particular land use (e.g., road building and maintenance) and are based on the best available science, legal obligations, and pragmatic experience (Switalski and Jones 2012).

While some BMPs currently exist for snowmobile use, they are presented in a piecemeal, resource-specific fashion, or only provide guidelines for trail building and maintenance. For example, the Forest Service has created BMPs for protecting water quality on its lands and gives some guidance on how to minimize impacts related to snowmobile route planning (USDA FS 2012). The Forest Service – as well as other land management agencies – also has guidance to pursue environmental collaboration and conflict resolution in addressing land management challenges generally (OMB CEQ 2012). The practice of collaboration and conflict resolution has been an increasing trend in recent years. For environmental collaboration to be successful, several key aspects have been identified, including: balanced stakeholder representation, clear goals and objectives, information exchange, and shared decision-making (Schuett et al. 2001). As the Forest Service begins travel planning, a comprehensive framework is essential to help managers implement the mandate to minimize social and environmental impacts in designating winter motorized routes and areas.

The next three articles present the best available science for studying the impacts of snowmobiles on recreation use conflict and natural resources including water quality, soils, vegetation, and wildlife. Building off of the literature and existing recommendations from researchers and managers, a framework is outlined for the minimization of snowmobile impacts. These best management practices (BMPs) provide guidelines to help Forest Service managers designate appropriate routes and areas as *open*, and to close inappropriate routes and areas. Additionally, these practices provide guidance on managing snowmobile use to be consistent with the Executive Orders minimization criteria and the Forest Service Travel Management Rule.

Monitoring, enforcement, and funding

Implementing the BMPs presented here will help create a more sustainable and manageable system of routes and areas that will limit impacts to natural resources and use conflicts. Key to any management action is monitoring the success or failure of a project or program and adapting the management strategy to reach the goal or objectives. Accordingly, the BMPs rely heavily on monitoring to ensure they are indeed reducing negative social and environmental impacts. Once management actions are implemented, enforcement is essential for the success of any management plan (Adams and McCool 2010). It is also very important that the Forest Service allocates adequate funding and resources to undertake travel planning efforts (Yankoviak 2005, Adams and McCool 2010). Education and outreach programs that reduce conflict between uses and increase compliance have also been implemented (Lindberg et al. 2009, USDI NPS 2013). However, data is limited on the success of these programs, and such efforts may need to be supplemented with monitoring and enforcement of existing regulations.

Yellowstone National Park has developed an extensive adaptive management program following the implementation of its winter use plan (USDI NPS 2013). Land managers identified key resources affected by motorized recreation, indicators for measuring their effects, and the most appropriate monitoring methods (Table 1). Using this framework, they are able to revisit management decisions to determine if they are effectively mitigating use conflicts and environmental concerns in the Park.

Table 1: Examples of adaptive management monitoring: affected resource, indicator, and monitoring method identification in Yellowstone National Park (reprinted from USDI NPS 2013).

Affected Resource	Indicator	Preliminary Monitoring Methods
Air Quality at the West Entrance and Old Faithful	Levels of: CO, PM10, and NO2	Fixed site monitoring for CO, PM10, and NO2
Soundscape directly adjacent to park roads	Audibility: decibel levels (dBA) in terms of magnitude and duration (constant sound level or Leq) sound is audible over an 8-hour period	Could include audibility logging, digital recordings, and sound pressure level measurement
Visitor Experience	Satisfaction	Visitor survey (pending OMB approval)
Wildlife on or near roads	Wildlife behavioral responses to OSV	Observational studies

Climate Change

Today's land managers have to plan in the context of a rapidly changing climate. This includes addressing rising temperatures, thinner snow packs, more intense storms, increased number of freeze/thaw cycles, and more rain-on-snow events which can damage trail systems and add additional management challenges (IPCC 2013). These changes in snow conditions as well as a receding snowpack and earlier spring run-off will alter future winter backcountry recreation use patterns.

With fewer or smaller areas available (and possibly a shortened timeframe with good snow conditions), use will be concentrated, which may lead to increased crowding, recreational conflict, and resource damage. For example, it is becoming more commonplace for snowmobiles to travel on dry roadbeds or snow-free trails to access the receding snowline. This direct contact with the ground can cause soil compaction, erosion, and water quality issues and lead to a whole new set of management concerns. In another example, grizzly bears may leave their dens earlier as climate changes, making previous seasonal management decisions obsolete. The trails themselves will need increased maintenance such as grading and clearing obstacles during snow-free months, upgrading culverts, building larger bridges, and moving routes from areas prone to flooding or rapid melting. The quality of snow, the number of days with good snow conditions, and quality of recreation experience may also be altered in some regions as there are more freeze-thaw cycles. To preserve quality recreation opportunities and minimize natural resource damage, land managers should consider the impacts of a changing climate when developing management direction.

CONCLUSION

The growing number of winter backcountry users has increased recreational use conflicts and negative impacts on natural resources. Climate change may also restrict where winter recreation takes place, further concentrating use and associated impacts. As the Forest Service begins formally addressing winter recreation though OSV travel planning and determines where motorized use is allowed, restricted, and prohibited, it is essential that land managers have the best available science to guide their important decisions. Furthermore, several management strategies have already been found to successfully mitigate these impacts.

This series of articles presents the best available science on the impacts of snowmobiles. Based upon this research and the recommendations of researchers and managers, and professional experience, a list of best management practices has been developed. If these BMPs are followed, they will help mitigate recreational use conflicts and minimize impacts to natural resources. Once a system of routes is established and special use areas are designated, effective enforcement and monitoring will be critical to the long-term success of any management plan.

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LITERATURE CITED

Adams, J.C., and S.F. McCool. 2010. Finite Recreation Opportunities: The Forest Service, the Bureau of Land Management, and Off-Road Vehicle Management. *Natural Resources Journal* 49:45-116.

Baker, E., and E. Bithmann. 2005. Snowmobiling in the Adirondack Park: Environmental and Social Impacts. St. Lawrence University, Canton, NY. http://it.stlawu.edu/~bart/Barthelmess/CB2005_final_papers/pdfs/snowmobiles.pdf

Bosworth, D. 2003. Four Threats to the Health of the Nation's Forests and Grasslands. USDA Forest Service, Washington, D.C. http://www.fs.fed.us/projects/four-threats

Cordell, H.K. 2012. Outdoor recreation trends and futures: a technical document supporting the Forest Service 2010 RPA assessment. General Technical Report SRS-150. USDA Forest Service, Southern Research Station. Asheville, NC. http://www.treesearch.fs.fed.us/pubs/40453

Davenport, J., and T.A. Switalski. 2006. Environmental Impacts of Transport Related to Tourism and Leisure Activities. In: J. Davenport and J. Davenport (eds.) *The Ecology of Transportation: Managing Mobility for the Environment*. Kluwer Academic Publishers. Dordrecht, Netherlands. P. 333-360.

Gaines, W.L., P.H. Singleton, and R.C. Ross. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-586. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/pubs/gtr586.pdf

IPCC. 2013. Climate Change 2013: *The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels,

Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York.

Lindberg, K., P. Fredman, and T. Heldt. 2009. Facilitating Integrated Recreation Management: Assessing Conflict Reduction Benefits in a Common Metric. *Forest Science* 55(3):201-209.

Manning, R.E., and W.A. Valliere. 2001. Coping in Outdoor Recreation: Causes and Consequences of Crowding and Conflict Among Community Residents. *Journal of Leisure Research* 33(4):410-426.

Office of Management and Budget, Council on Environmental Quality (OMB CEQ). 2012. Memorandum on Environmental Collaboration and Conflict Resolution. Washington, D.C. 9p. http://georgewbush-whitehouse.archives.gov/ceq/joint-statement.html

Ouren, D.S., C. Haas, C.P. Melcher, S.C. Stewart, P.D. Ponds, N.R. Sexton, L. Burris, T. Fancher, and Z.H. Bowen. 2007. Environmental effects of off-highway vehicles on Bureau of Land Management Lands: a literature synthesis, annotated bibliographies, extensive bibliographies, and internet resources: U.S. Geological Survey, Open-File Report 2007-1353. http://www.fort.usgs.gov/products/publications/22021/22021.pdf

Rivers, K.E., and M. Menlove. 2006. Winter recreation on western national forest lands: a comprehensive analysis of motorized and non-motorized opportunity and access. Published by Winter Wildlands Alliance, Boise, ID. http://winterwildlands.org/wp-content/uploads/2014/04/Winter-Recreation-on-Western-National-Forests-WWA_2006.pdf

Schuett, M.A., S.W. Selin, and D.S. Carr. 2001. Making It Work: Keys to Successful Collaboration in Natural Resource Management. *Environmental Management* 27(4):587–593.

Stokowski, P.A., and C.B. LaPointe. 2000. Environmental and social effects of ATVs and ORVs: an annotated bibliography and research assessment. School of Natural Resources, University of Vermont.

Switalski, T.A., and A. Jones. 2012. Off-Road Vehicle Best Management Practices for Forestlands: A Review of Scientific Literature and Guidance for Managers. *Journal of Conservation Planning* 8:12-24.

USDA Forest Service (FS). 2012. National best management practices for water quality management on national forest system lands - Volume 1: national core BMP technical guide FS-990a. Washington, D.C. http://www.fs.fed.us/biology/ resources/pubs/watershed/FS_National_Core_BMPs_April2012.pdf

USDI National Park Service (NPS). 2011. Scientific assessment of Yellowstone National Park winter use March 2011. Yellowstone National Park, Mammoth, WY. http://www.nps.gov/yell/parkmgmt/upload/yell_sci_assessment_deis_release_2011.pdf

USDI National Park Service (NPS). 2013. Yellowstone National Park winter use plan / supplemental environmental impact statement February 2013. Yellowstone National Park, Mammoth, WY. http://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

Winter Wildlands Alliance (WWA). 2014. Environmental impacts from snowmobile use. Published by Winter Wildlands Alliance, Boise, ID. http://winterwildlands.org/wp-content/uploads/2014/05/Environmental-Impacts-from-Snowmobile-Use.pdf

Yankoviak, B.M. 2005. Off-road vehicle policy on USDA national forests: evaluating user conflicts and travel management. MS Thesis: University of Montana, Missoula, MT.

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Snowmobile Best Management Practices for Forest Service Travel Planning: A Comprehensive Literature Review and Recommendations for Management – *Water Quality, Soils, and Vegetation*

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ABSTRACT: Since the seminal research of Wallace Wanek and his colleagues in the 1970s, it has been well established that snowmobiles can negatively impact water quality, soils, and vegetation. However, while early researchers focused on localized impacts of snowmobiles on groomed trails, today's machines also travel off-trail and into many sensitive habitats such as alpine cirques, meadows, and wetlands. Water quality can also be affected when spring runoff releases pollutants stored in the snowpack – especially at staging areas. Furthermore, as snowmobiles become increasingly powerful, their increased torque and reach creates a potential for greater impact on those resources. Based on this research and existing management strategies, we present best management practices (BMPs) which will help protect water quality, soils, and vegetation.

Keywords: Travel planning, snowmobiles, best management practices, BMPs, water quality, soils, vegetation, USDA Forest Service

Water Quality Research

Protecting and enhancing water supply is a key mandate of the USDA Forest Service (Forest Service), and a number of aquatic species and municipal watersheds depend on National Forests – especially in the West. For example, most National Forest acres west of the Cascade Mountains in Oregon and Washington are municipal watersheds and provide water to local communities (USDA FS 2000). During the winter, snowmobiles release toxins such as ammonium, nitrate, sulfate, benzene, and toluene which accumulate in the snowpack (Ingersol 1999) and increase acidity (Musselman and Kormacher 2007). In the spring runoff, accumulated pollutants are released as a pulse into the soil, groundwater, and surrounding waterbodies.

A recent study found snowmobiles are polluting a tributary of Lake Tahoe, CA. Examining 168 different semi-volatile organic compounds (SVOC), McDaniel (2013) found eight to 20 times greater loadings on snowmobile trails than background levels. He further reported that highly toxic and persistent polycyclic aromatic hydrocarbons (PAHs) had increased two to six times the background level in a nearby stream (McDaniel 2013). Impacts on water quality can be especially pronounced at trailheads and staging areas where snowmobiles congregate (USDA FS 2012). Lakes can also be vulnerable because snow melts directly into the waterbody without any vegetative buffer, and there is a risk of snowmobiles falling through thin ice and spilling toxins directly into the water (USDA FS 2012).

Soils Research

Snowmobiles can directly impact soils in a number of ways including soil compaction, erosion, and contamination. When traveling in areas of low or no snow – such as such as wind-swept ridges, snow-free access points, or during periods of thin snowpack – snowmobiles can be particularly damaging. This may also be an increasingly common situation as climate change leaves low-elevation access points snow-free for longer periods of time. Snowmobiles can also indirectly impact soils through snow compaction (Wanek 1971). Weighing several hundred pounds, snowmobiles easily compact the snow, which can increase snowpack density, reduce soil temperatures, increase soil freezing, and result in a later melt-out (Gage and Cooper 2009).

In areas of low or no snowpack, direct soil compaction can occur from snowmobiles leading to erosion (Gage and Cooper 2009). On steep slopes – especially south facing, or wind-swept slopes – vegetation and snow can be mechanically removed from snowmobile tracks resulting in exposed bare ground (Stagl 1999). Soil compaction impacts nearly all properties and functions of soil including increased bulk density and reduced pore space leading to reduced permeability of water and air (Batey 2009). This results in surface erosion, especially on steep slopes (Batey 2009). Soil erosion when located near streams can also lead to localized stream sedimentation and increased turbidity. As climate change increases the number of snow-free days, erosion from snowmobiles will be an increasing management concern.

Soils can also be contaminated when pollutants enter the soil from a melting snowpack. With inefficient engines, snowmobiles release much of their oil gas mixture into the snow unburned. Several pollutants have been recorded in the snowpack along snowmobile trails including ammonium, nitrate, sulfate, benzene, and toluene (Ingersol 1999). In the spring, these pollutants are released into the soil, creating local contamination and associated impacts.

Vegetation Research

Snowmobiles impact vegetation either through directly crushing and breaking vegetation, or through a number of indirect mechanisms. When traveling off-trail, snowmobiles often run over trees and shrubs causing damage or death – often with minimal snowmobile traffic. Although these impacts may not be environmentally significant when they occur in robust forest environments, they can be very significant when they occur in sensitive forest habit, such as high mountain slopes or meadows.

A recent study on the Gallatin National Forest (MT) found 366 acres of trees damaged by snowmobiles on timber sale units – slowing forest regeneration (WWA 2009, Table 1). Trees such as white-bark pine (*Pinus albicaulis*), found only at high elevations and declining across its range, may be vulnerable to snowmobile damage. Trampling has also been found to result in a reduction in plant productivity, changes in the plant community, and a reduction in plant diversity (Masyk 1973, Wanek 1973, Wanek and Schumacher 1975).

Compaction of the snow reduces the insulating air spaces and conducts cold air to the ground (Wanek 1973). These lower temperatures can reduce plant density and composition (Neumann and Merriam 1972), reduce productivity and growth (Wanek and Potter 1974), delay seed germination and flowering (Rongstad 1980), as well as affect decomposition rates, hummus formation and microbial activity (Neumann & Merriam 1972, Rongstad 1980). These impacts ultimately can change community structure and reduce the availability and duration of spring wildlife foods (Stagl 1999).

Table 1. Summary of snowmobile damaged trees on the Gallatin National Forest (MT) reported during regeneration transect surveys of previously logged timber stands (reprinted from WWA 2009).

Area name	Year logged	Year inventoried	Acres	Average # damaged trees per acre	Total number of trees damaged
Little Teepee Creek Drainage	1969	1995	122	140	17,080
Horse Butte Road*	1992	1995	15	514*	7710*
Madison Arm	1991	1995	12	5	60
Unknown	1960s	1983	68	23	1564
Unknown*	1960s	1983	100	652*	65,200*
Cream Creek*	1986	1995	60	725*	43,500*
Total damaged trees:					**135,114**

*surveys note the presence of a snowmobile trail in this stand

Water Quality, Soils, and Vegetation Management

The most common strategy for protecting water quality, soils, and vegetation from snowmobile impacts is to ensure that there is adequate snow cover and create a buffer around waterways. For example, the Forest Service has developed best management practices (BMPs) to protect water resources on Forest Service lands from snowmobile pollution (USDA FS 2012). This document recommends, "Allow over-snow vehicle use cross-country or on trails when snow depths are sufficient to protect the underlying vegetative cover and soil or trail surface; use and enforce closure orders to mitigate effects when adverse effects to soil, water quality, or riparian resources are occurring; use suitable measures to trap and treat pollutants from over-snow vehicle emissions in snowmelt runoff or locate the staging area at a sufficient distance from nearby waterbodies to provide adequate pollutant filtering" (USDA FS 2012, p. 96-97).

Some Forest Service policy has also recommended restricting snowmobile use to protect water quality. The Uinta-Wasatch-Cache National Forest (UT) does not allow recreational snowmobiling in Salt Lake City's municipal watershed (USDA FS 2003). The Inyo, Sequoia, and Sierra National Forests are proposing a minimum of 18" of snowpack before allowing snowmobiling in their revised Forest Plan to protect forest resources (USDA FS 2014). Restricting snowmobile use in sensitive habitats such as riparian areas and wetlands can be helpful in mitigating these impacts as well.

Best Management Practices for Water Quality, Soils, and Vegetation

Designating motorized use

1. Set dates for snowmobile season opening and closure, and adjust based upon adequate snow depth.

2. Require a minimum snow depth of at least 0.3m (12 in), or sufficient depth to protect water quality, soils, and vegetation before a contingency plan and implement emergency closures if snowpack goes below this threshold.

3. Require a minimum snow depth of at least 0.45 m (18 in), or sufficient depth to protect water quality, soils, and vegetation before allowing snowmobiling off-trail. Have a contingency plan and implement emergency closures if snowpack goes below this threshold.

4. Avoid locating snowmobile routes or areas in municipal watersheds.

5. Restrict snowmobile use on wetlands, riparian areas, and sensitive meadows and buffer snowmobile trailheads and routes 45 m (150 ft) from these areas.

Minimizing impacts of motorized use

1. Develop public information, educational programs, and signage about the impacts of snowmobiles on water quality, soils, and vegetation and how to minimize those impacts.

2. Ensure adequate maintenance of bridges and culverts on routes to help prevent erosion during the spring run-off.

3. If roads are only used for snowmobile use, scarify the roadbed to restore hydrology.

4. Encourage or require the use of best available technology (BAT) where necessary to minimize the impacts water quality, soils, and vegetation.

5. Close routes and areas when excessive damage to soils and vegetation has occurred, and/or erosion has been documented.

6. Monitor closed routes and areas to ensure the measures taken are effectively mitigating impacts to water quality, soils, and vegetation.

7. Establish an adaptive management framework using monitoring to determine efficacy of current management.

8. Revisit plan decisions as necessary to ensure impacts to water quality, soils, and vegetation are being minimized and motorized impacts are below accepted thresholds.

CONCLUSION

It has been well documented that snowmobiles can impact water quality, soils, and vegetation. Alpine environments are particularly sensitive to disturbance, and snowmobiles can pollute waterways, cause localized soil erosion, and crush and break vegetation. Many of these impacts are compounded by climate change which is leaving many "historic" access points snow-free for much of the winter. Ensuring that there is adequate snow cover and buffered waterways are key mitigation strategies. Restricting use in sensitive habitats such as riparian areas and wetlands is also an important mitigation step. Applying BMPs in the development of a system of snowmobile routes and areas will protect water quality, soils, and vegetation on Forest Service lands.

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LITERATURE CITED

Batey, T. 2009. Soil Compaction and Soil Management – a review. Soil Use and Management 25:335–345.

Gage, E., and D.J. Cooper. 2009. Winter recreation impacts to wetlands: a technical review. Prepared for Arapaho-Roosevelt National Forests, White River National Forest, and Black Hills National Forest. Colorado State University, Fort Collins, CO.

Ingersoll, G.P. 1999. Water-resources investigations report: effects of snowmobile use on snowpack chemistry in Yellowstone National Park, 1998. U.S. Geological Survey, Denver, CO.

Keddy, P.A., Spavold, A.J., Keddy, C.J. 1979. Snowmobile Impact on Old Field and March Vegetation in Nova Scotia Canada: An Experimental Study. Environmental Management 3(5):409-415.

Masyk, W. J. 1973. Snowmobile, a recreation technology in Banff National Park: environmental impact and decision-making. University of Calgary and the University of Western Ontario, London, Ontario, Canada.

McDaniel, M.R. 2013. Semivolatile organic compounds in snowmobile emissions and in the snowpack and surface water in Blackwood Canyon, Lake Tahoe, CA. Dissertation, University of Nevada, Reno.

Musselman, R.C. and J.L. Korfmacher. 2007. Air Quality and Snow Chemistry at a Snowmobile Staging Area in a Rocky Mountain Subalpine Forest, Snowy Range, Wyoming. Environmental Monitoring and Assessment 133:321-334.

Neumann, P. W., and H. G. Merriam. 1972. Ecological effects of snowmobiles. Canadian Field Naturalist 86:207–212.

Rongstad, O.J. 1980. Research needs on environmental impacts of snowmobiles. In: Andrews RNL and Nowak P (eds.) Off-Road Vehicle Use: A Management Challenge. US Department of Agriculture Office of Environmental Quality. Washington, D.C.

Stangl, J.T. 1999. Effects of Winter Recreation on Vegetation. In: T. Olliff, K. Legg, and B. Kaeding, (eds.) Effects of Winter Recreation on Wildlife of the Greater Yellowstone Area: a Literature Review and Assessment. Report to the Greater Yellowstone Coordinating Committee. Yellowstone National Park, WY. Pp.119-121.

USDA Forest Service (FS). 2000. Water and the Forest Service. USDA Forest Service policy analysis. Washington, D.C. http://www.fs.fed.us/publications/policy-analysis/water.pdf

USDA Forest Service (FS). 2003. Revised Forest Plan Wasatch-Cache National Forest. Salt Lake City, UT.

USDA Forest Service (FS). 2012. National best management practices for water quality management on national forest system lands - Volume 1: national core BMP technical guide FS 990a. Washington, D.C. http://www.fs.fed.us/biology/resources pubs/watershed/FS_National_Core_BMPs_ April2012.pdf

USDA Forest Service (FS). 2014. Detailed proposed action in support of the need to change items in the notice of intent for Forest Plan revision for the Inyo, Sequoia and Sierra National Forests. R5-MB-276.

Wanek, W.J. 1971. Snowmobiling impact on vegetation, temperatures and soil microbes. Pages 117–130 in Snowmobile and Off-Road Vehicle Research Symposium Proceedings. Technical Report Number 8. Department of Park and Recreation Resources, Michigan State University, Lansing, MI.

Wanek, W.J. 1973. Ecological impact of snowmobiling in Northern Minnesota. Pages 57–76 in Snowmobile and Off-Road Vehicle Research Symposium Proceedings. Technical Report Number 9. Department of Park and Recreation Resources, Michigan State University, Lansing, MI.

Wanek, W.J. 1974. A continuing study of the ecological impact of snowmobiling in northern Minnesota. Final Research Report for 1973-74. The Center for Environmental Studies, Bemidji State College, Bemidji, MN. 54p.

Wanek W.J. and L. H. Schumacher. 1975. A continuing study of the ecological impact of snowmobiling in northern Minnesota. Final report for 1974–75. State College, Bemidji, MN.

Winter Wildlands Alliance (WWA). 2009. Seeing the forest and the trees: assessing snowmobile tree damage in national forests. A report by Winter Wildlands Alliance, Boise, ID. http://209.200.74.232/resources/reports/WWA_Treetop_ Damage_Report_final.pdf

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Snowmobile Best Management Practices for Forest Service Travel Planning: A Comprehensive Literature Review and Recommendations for Management – *Wildlife*

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ABSTRACT: Snowmobiles can have a number of impacts on wildlife including physiological responses such as increased heart rate and elevated stress level, behavioral responses such as displacement and avoidance, as well as facilitating sources of competition, and/or increasing hunting, trapping, and poaching mortality. This article highlights the impacts of snowmobiles on three species of special concern because their populations are in decline or vulnerable, and they have state and/or federal legal protections: grizzly bears (*Ursus arctos*), wolverine (*Gulo gulo*), and Canada lynx (*Lynx canadensis*). As supported below, these three species are highly susceptible to snowmobile noise and disturbance, and need additional management actions to ensure winter recreation does not compromise their recovery. We also highlight research on the impact of snowmobiles on ungulates which are managed as game species and also need special management considerations. Based on this research and current management strategies, we present a set of best management practices (BMPs) which will help these sensitive species recover on National Forest lands.

Keywords: Travel planning, snowmobiles, best management practices, BMPs, wildlife, grizzly bear, wolverine, Canada lynx, ungulates, USDA Forest Service

INTRODUCTION

While many animals are well adapted for survival in the winter, deep snow and cold temperatures can limit foraging opportunities and increase metabolic demands. Snowmobiles can add to animals' vulnerability during this critical time by eliciting physiological responses such as increased heart rate and elevated stress level; eliciting behavioral responses including displacement and avoidance; facilitating sources of competition; and/or increasing hunting, trapping, and poaching mortality (for a review see Gaines et al. 2003, Figure 1, Table 1). These impacts can result in declines in animal health, fragmented wildlife populations, and potential population declines (Gaines et al. 2003). In this article, we focus on snowmobile impacts on three species that are in decline or vulnerable and have special legal protections. Additionally, we present research and management strategies for reducing the impacts of snowmobiles on ungulates. The increased popularity of winter recreation and the potential for climate change concentrating their use makes mitigating the impacts of snowmobiles very timely.

Figure 1. Interactions between the 29 focal wildlife species and snowmobile routes documented from a comprehensive literature review (reprinted from Gaines et al. 2003).

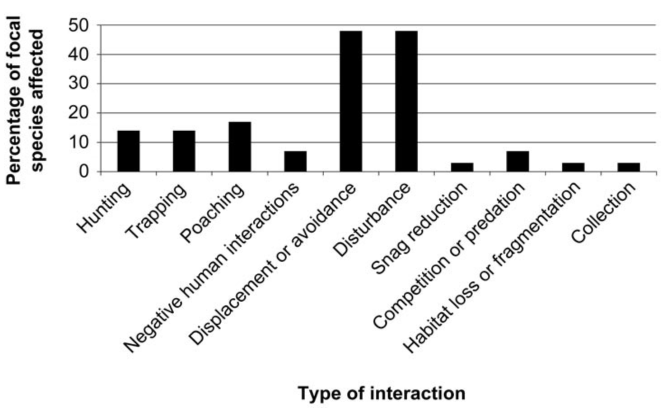


Table 1. Snowmobile route associated factors for wide-ranging carnivores and ungulate focal species (adapted from Gaines et al. 2003).

Focal species	Scientific name	Snowmobile route associated factors
Grizzly bear	*Ursus arctos*	Disturbance at a specific site
Wolverine	*Gulo gulo*	Trapping Disturbance at a specific site
Lynx	*Lynx canadensis*	Route for competitors or predators Trapping Disturbance at a specific site
Gray wolf	*Canis lupus*	Trapping Physiological response
American marten	*Martes americana*	Trapping
Fisher	*Martes pennanti*	Trapping Displacement or avoidance
Mule deer	*Odocoileus hemionus*	Displacement or avoidance Disturbance at a specific site
Elk	*Cervus canadensis*	Displacement or avoidance Disturbance at a specific site Physiological response
Bighorn sheep	*Ovis canadensis*	Displacement or avoidance Disturbance at a specific site Physiological response

Grizzly Bear

Grizzly bears (*Ursus arctos*) are a Threatened Species under the U.S. Endangered Species Act and protected from harm across their range in the continental United States. Their denning habitat often overlaps with winter recreation areas, making them susceptible to disturbance, thus increasing energy expenditures and the potential of den abandonment (Linnell et al. 2000). Direct mortality is also possible if an avalanche is triggered on a slope where the bears are hibernating (Hilderbrand 2000).

Grizzly bears typically den in relatively high elevation areas with more stable snow conditions and steep slopes (Linnell et al. 2000). In general, grizzlies avoid roads (Mace et al. 1996) and typically select den sites one to two kilometers from human activity (Linnell et al. 2000). However, snowmobiles can easily access these remote sites, posing the potential for disturbance. No systematic data set exists on how denning bears react to snowmobile disturbance, but a comprehensive review on the topic found that human disturbance within one kilometer of a den site has a significant risk of abandonment, especially early in the denning season (Linnell et al. 2000).

Grizzly Bear Management

Although grizzly bears can be susceptible to disturbance and the risk of den abandonment, careful management of winter recreation can help avoid this conflict. Linnell et al. (2000) recommended that "winter activities should be minimized in suitable or traditional denning areas; if winter activity is unavoidable, it should begin around the time bears naturally enter dens, so that they can choose to avoid disturbed areas; and winter activity should be confined to regular routes as much as possible" (Linnell et al. 2000, pgs. 409-410). Podrunzney et al. (2000) modeled the overlap of potential grizzly bear denning habitat and potential snowmobile use areas on the Gallatin National Forest (MT). This model was used in USDA Forest Service (Forest Service) travel planning and allowed managers to plan snowmobile routes and areas to avoid conflict with grizzly bears. Similar modeling efforts have been conducted in Alaska incorporating both motorized and non-motorized recreation with bear denning habitat (see Goldstein et al. 2010).

Because the grizzly bear is a federally protected Threatened Species, the U.S. Fish and Wildlife Service (USFWS) considers snowmobile disturbance as a potential "take," thus requiring management actions. In a recent Biological Opinion for snowmobiling on the Flathead National Forest (MT), the USFWS required Forest land managers to "quantify and monitor snowmobile use… and ensure adequate protection to known and discovered grizzly bear den sites and post-emergent females with cubs" (USDI FWS 2008, p. 57). In 2014, the Flathead National Forest closed the Skyland / Challenge snowmobile play area due to the emergence of a grizzly bear in the area. As climate change results in bears leaving dens earlier, agency authority and flexibility to close areas will become increasingly important.

Limiting open motorized route density is a key management action to increase grizzly bear habitat security. For example, USDA FS (2011) recommends limiting open motorized route density to less than 1 mile per square mile in much of the Cabinet-Yaak Recovery Area (MT). State-level management plans also address management of snowmobiles in grizzly bear habitat. For example, The Montana Forested State Trust Lands Habitat Conservation Plan calls for minimizing road miles and restricting public access (including snowmobiles) on roads in important grizzly bear habitat areas and seasons (MT DNRC 2011).

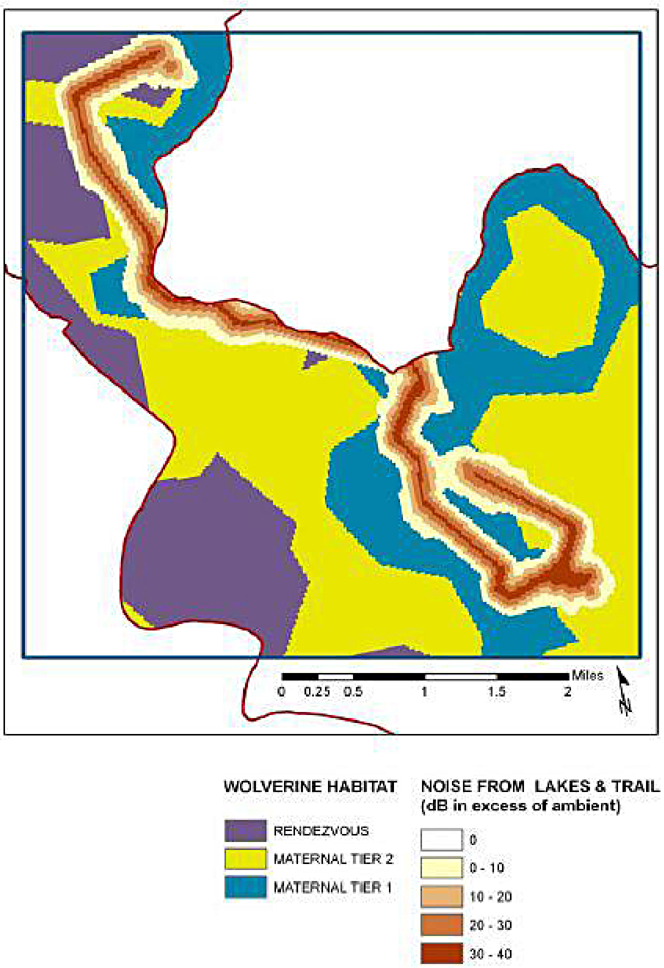
Wolverine

Wolverine (*Gulo gulo*) are rare, long-ranging carnivores that spend most of their lives in high elevation areas (Aubry et al. 2007). While they roam hundreds, sometimes thousands of miles seeking food and mates, in the heart of the winter females dig dens in the snowpack and give birth. Little has been known about this elusive carnivore until recently when it was petitioned for listing under the Endangered Species Act, resulting in a flurry of research studies. Wolverine are a Species of Special Concern in Montana, classified as a Sensitive Species by the Forest Service, and trapping has been banned across their range in the continental United States.

In general, wolverine are sensitive to human disturbance. Studies in Canada reveal that wolverine have been found to be much more common in protected areas than in multiple-use landscapes (Fisher et al. 2013, Whittington et al. 2014). Snowmobile use commonly overlaps with wolverine denning habitat, and the noise may cause female wolverine to abandon their denning sites, potentially reducing reproductive success.

One on-going, five-year study examines the impact of winter recreation on wolverine in multiple mountain ranges in Montana and Idaho (Heinemeyer and Squires 2013). Preliminary results suggest that in areas with winter backcountry use, denning female wolverine move more frequently, move at higher rates when in higher intensity recreation areas, and move more during the weekend when there is more human use (Heinemeyer and Squires 2013). These impacts are creating "significant additive energetic effects on wolverine during the critical winter and denning periods" (Heinemeyer and Squires 2013, p. 5). While the majority of the research sites studied are snowmobile use areas, the ongoing study is adding more sites where non-motorized backcountry skiers recreate as well. However, researchers have noted that limitations on the distance that skiers can travel often allows for core denning habitat to be available beyond the reach of backcountry skiers (Heinemeyer et al. 2014).

Figure 2. An example of using the SPreAD model to identify the overlap of snowmobile noise emissions and wolverine habitat types (Reed et al. 2009).



Wolverine Management

Wolverine have very large home ranges and need large blocks of interconnected habitat. Key management schemes for protecting wolverine include limiting disturbance, and retaining and restoring habitat connectivity. Managers can reduce the potential conflict between snowmobiles and wolverine by identifying areas of overlap and managing accordingly. For example, The Wilderness Society developed the SPreAD-GIS model that can model snowmobile sound propagation overlap with wolverine denning habitat (Reed et al. 2009, Figure 2). Two other sound propagation models, the Integrated Noise Model and the Noise Simulation Model (USDI NPS 2013), have also been used by Yellowstone National Park to model over-snow vehicle audibility.

In the face of climate change, wolverine may lose much of their denning habitat as persistent snowfields disappear (Fisher et al. 2013), and connectivity among remaining habitat patches will become increasingly important (Schwartz et al. 2009). The 2014 Management Plan for the Conservation of Wolverines in Idaho calls for identifying wolverine linkage areas at local and regional scales and pro-actively conserving them (IDFG 2014).

Canada Lynx

Canada lynx (*Lynx canadensis*) is a Threatened Species under the U.S. Endangered Species Act. They are adapted to deep snow conditions, allowing them to thrive in habitats where potential competitors and predators such as coyotes (*Canis latrans*) cannot easily survive. However, compacted snow trails and snowmobile play areas help facilitate coyote movement into Canada lynx habitat. While one study in Montana found limited use of snowmobile trails by coyotes (Kolbe et al. 2007), studies in Utah and Wyoming documented coyotes using compacted trails extensively, resulting in potential competition and displacement of Canada lynx (Bunnell et al. 2006, Gese et al. 2013, Dowd et al. 2014). The differences in results are probably due to distinct regional snow characteristics, predator communities, and snowmobile use (Bunnell et al. 2006). While both snowmobiles and skis create trails that coyotes could exploit, snowmobiles can travel an order of magnitude farther in a day than non-motorized users.

Canada Lynx Management

Both researchers and managers have recommended limiting snowmobile routes in Canada lynx habitat. Following their research on coyotes' use of snowmobile trails, Dowd et al. (2014) suggest that "limiting the expanse of groomed trail systems may minimize coyote encroachment into these deep snow environments" (p.39). The Canada Lynx Assessment and Conservation Strategy set planning standards on Forest Service lands that include, "Consider not expanding designated over-the-snow routes or designated play areas in lynx habitat, unless the designation serves to consolidate use" (ILBT 2013, p.94).

Ungulates

Ungulates are hoofed animals including deer (*Odocoileus spp.*), elk (*Cervus canadensis*), moose (*Alces alces*), mountain goat (*Oreamnos americanus*), and bighorn sheep (*Ovis canadensis*). All of these animals are highly prized game species. Bighorn sheep are classified as a Sensitive Species by the Forest Service, and two subspecies – Nelson's Peninsular and Sierra Nevada bighorn sheep – are listed as Endangered Species. It has been well established that undisturbed "winter range" is essential for ungulates survival (Canfield et al. 1999).

Studies have found that snowmobiles can exhibit both a physiological and behavioral response on a number of ungulate species (Gaines et al. 2003, Table 1). Recent studies in Yellowstone National Park found elk experienced increased stress (Creel et al. 2002) and actively responded (Borkowski et al. 2006) when approached by snowmobiles. A recent study on moose in Scandinavia also found disturbance and displacement following snowmobile activity (Neumann et al. 2011). Bighorn sheep and mountain goats are particularly susceptible to the effects of disturbance because they are limited to relatively small areas of suitable habitat with very steep and rocky slopes (Canfield et al. 1999).

Ungulate Management

Limiting disturbance on ungulates, especially in winter range, is a key management strategy. For example, in their review of the impact of recreation on Rocky Mountain ungulates, Canfield et al. (1999) suggest keeping motorized routes and trails away from wintering areas, and they recommend establishing designated travel routes to make human use as predictable as possible. Further, Harris et al. (2014) recently reviewed the impacts of winter recreation on northern ungulates and highlighted the importance of limiting the duration and spatial footprint of disturbance.

Yellowstone National Park has implemented a number of policies to reduce disturbance from snowmobiles. Some of these practices include: limiting the number of snowmobiles, requiring best available technology (BAT), setting speed limits of 56 kph (35mph), and establishing open and closure dates (USDI NPS 2013). These practices have been coupled with monitoring and complementary research projects which can measure the effectiveness of the management plan. For example, Borkowski et al. (2006) stated that snowmobile regulations in Yellowstone, including intensities and travel routes, "were effective at reducing disturbances to bison and elk below a level that would cause measurable fitness effects" (p.1).

Best Management Practices for Wildlife

Designating motorized use

Based on the best available scientific research and successful management strategies, a set of best management practices (BMPs) has been created to guide effective and timely land management decisions and actions so that sensitive species will recover on National Forest lands.

1. Identify routes and areas where there is the potential for snowmobile disturbance of key wildlife including grizzly bear, wolverine, lynx, and ungulate winter range using survey data or GIS modeling. Survey information should be catalogued and regularly updated in a GIS database.

2. Locate motorized routes and areas:

    a. where disturbance is unlikely to significantly affect viability or recovery of listed or petitioned threatened or endangered species:

        i. limit snowmobile routes and areas in grizzly bear suitable denning habitat, wolverine denning habitat, and Canada lynx Critical Habitat.

ii. reduce snowmobile route density to below 0.6 km/km^2 (1 mi/mi^2) in occupied habitat.

b. outside proposed Wilderness Areas, Wilderness Study Areas and Research Natural Areas.

c. in discrete, specified areas bounded by natural features (topography and vegetative cover) to provide visual and acoustic barriers and to ensure that secure habitat is maintained for wildlife.

d. outside critical ungulate wintering habitat.

3. Set dates for snowmobile season opening and closure, and adjust based upon seasonal wildlife needs including:

a. critical ungulate wintering habitat/winter concentration areas (e.g., December through March in Rockies).

b. grizzly bear denning season (mid-November), and emergence time (mid-April).

4. Limit or close routes and play areas with known bighorn sheep and mountain goat populations.

5. Limit or close areas to off-road and over-snow vehicle use in areas where antler shed hunting is prevalent.

6. Limit the number of routes and restrict off-trail use in key wildlife corridors.

7. Maintain large unfragmented, undisturbed, and connected blocks of forestland and alpine habitat where no snowmobile routes are designated.

Minimizing impacts of motorized use

1. Implement outreach programs to raise public awareness of winter wildlife habitat, wildlife behavior, and ways to minimize user impacts.

2. Encourage or require the use of best available technology (BAT) where necessary to limit disturbance on sensitive species.

3. Close snowmobile routes and areas if a grizzly bear emerges from its den in the area.

4. Monitor closed and open areas to ensure they are effectively mitigating impacts to wildlife, and not being used illegally.

5. Establish an adaptive management framework using monitoring to determine efficacy of current management.

6. Revisit plan decisions as necessary to ensure wildlife impacts are being minimized and motorized impacts are below accepted thresholds.

CONCLUSION

The growing number of winter backcountry users has increased the negative impacts on wildlife. Snowmobiles in particular can impact sensitive and hunted species. Grizzly bears' denning habitat overlaps with winter recreation areas, and snowmobiles can increase bears' energy expenditures and the risk of den abandonment. Wolverine can be disturbed by snowmobiles with significant additive energetic effects during critical denning periods. Canada lynx are also impacted by snowmobiles by introducing competitors into their habitat. Furthermore, ungulates, in response to snowmobile activity, exhibit both physiological and behavioral responses. Climate change may alter the behavior of wildlife as well, and most likely will concentrate snowmobile use – resulting in a need to pro-actively address the management of affected species. Identifying routes and areas where snowmobile activity and sensitive species habitat overlap is a necessary first step, and limiting snowmobiles in these areas is a key management action. Seasonal closures and use of best available technology can also limit impacts to these species.

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LITERATURE CITED

Aubry, K.B., K.S. Mckelvey, and J.P. Copeland. 2007. Distribution and Broad-Scale Habitat Relations of the Wolverine in the Contiguous United States. Journal of Wildlife Management 71(7):2147–2158.

Borkowski, J.J., P.J. White, R.A. Garrott, T. Davis, A.R. Hardy, and D.J. Reinhart. 2006. Behavioral Responses of Bison and Elk in Yellowstone to Snowmobiles and Snow Coaches. Ecological Applications 16:1911–1925.

Bunnell, K. D., J.T. Flinders, and M.L. Wolfe. 2006. Potential Impacts of Coyotes and Snowmobiles on Lynx Conservation in the Intermountain West. Wildlife Society Bulletin 34:828–838.

Canfield, J.E., L.J. Lyon, J.M. Hillis, and M.J. Thompson. 1999. Ungulates. Pages 6.1-6.25 in G. Joslin and H. Youmans, coordinators. Effects of Recreation on Rocky Mountain Wildlife: A Review for Montana. Committee on Effects of Recreation on Wildlife, Montana Chapter of The Wildlife Society. 307p.

Creel, S., J.E. Fox, A.R. Hardy, J. Sands, B. Garrot, and R.O. Peterson. 2002. Snowmobile Activity and Glucocorticoid Stress Responses in Wolves and Elk. Conservation Biology 16(3): 809-14. http://www.montana.edu/wwwbi/staff/creel/snomoGC.pdf

Dowd, J.L.B., E.M. Gese, and L.M. Aubry. 2014. Winter Space Use of Coyotes in High-Elevation Environments: Behavioral Adaptations to Deep-Snow Landscapes. Journal of Ethology 32:29-41.

Fisher, J.T., S. Bradbury, B. Anholt, L. Nolan, L. Roy, J.P. Volpe, and M. Wheatley. 2013. Wolverines (Gulo gulo luscus) on the Rocky Mountain Slopes : Natural Heterogeneity and Landscape Alteration as Predictors of Distribution. Canadian Journal of Zoology 91:706–716.

Gaines, W.L., P.H. Singleton, and R.C. Ross. 2003. Assessing the cumulative effects of linear recreation routes on wildlife habitats on the Okanogan and Wenatchee National Forests. Gen. Tech. Rep. PNW-GTR-586. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. http://www.fs.fed.us/pnw/pubs/gtr586.pdf

Gese, E., J.L.B. Dowd, and L. Aubry. 2013. The Influence of Snowmobile Trails on Coyote Movements During Winter in High-Elevation Landscapes. Plos One 8:1-10.

Goldstein, M.I., A.J. Poe, L.H. Suring, R. M. Nielson, and T.L. McDonald. 2010. Brown Bear Den Habitat and Winter Recreation in South-Central Alaska. Journal of Wildlife Management 74:35–42.

Harris G., R.M. Nielson, and T. Rinaldi. 2014. Effects of Winter Recreation on Northern Ungulates with Focus on Moose (Alces alces) and Snowmobiles. European Journal of Wildlife Resources 60:45–58.

Heinemeyer, K., and J. Squires. 2013. Wolverine – winter recreation research project: investigating the interactions between wolverines and winter recreation 2013 progress report. Round River Conservation Studies. Salt Lake City, UT. http://www.roundriver.info/wp-content/uploads/2013/11/Final-Idaho-Wolverine-Winter-Recreation-Project-2013-Progress-Report-16Nov13.pdf

Heinemeyer, K., J. Squires., and M. Hebblewhite. 2014. Wolverine responses to winter recreation. Presentation at the North American Congress for Conservation Biology. July 13 - 16. Missoula, MT.

Hilderbrand, G.V., L.L. Lewis, J. Larrivee, and S.D. Farley. 2000. A Denning Brown Bear, Ursus arctos, Sow and Two Cubs Killed in an Avalanche on the Kenai Peninsula, Alaska. Canadian Field-Naturalist 114(3): 498.

Idaho Department of Fish and Game (IDFG). 2014. Management plan for the conservation of wolverines in Idaho. Idaho Department of Fish and Game, Boise, ID. http://fishandgame.idaho.gov/public/wildlife/planWolverine.pdf

Interagency Lynx Biology Team (ILBT). 2013. Canada lynx conservation assessment and strategy. 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. 128 pp.

Kolbe, J.A., J.R. Squires, D.H. Pletscher, and L.F. Ruggiero. 2007. The Effect of Snowmobile Trails on Coyote Movements Within Lynx Home Ranges. Journal of Wildlife Management 71:1409-1418.

Linnell, J.D.C., J.E. Swenson, R. Andersen, B. Brain. 2000. How Vulnerable are Denning Bears to Disturbance? Wildlife Society Bulletin 28(2):400-413.

Mace, R.D., J.S. Waller, T.L. Manley, L.J. Lyon, and H. Zuuring. 1996. Relationships Among Grizzly Bears, Roads and Habitat in the Swan Mountains, MT. Journal of Applied Ecology 33:1395-1404.

Montana Department of Natural Resources (MT DNRC). 2011. Forested state trust lands habitat conservation plan (HCP). Final Environmental Impact Statement (EIS), September 17, 2010.

Neumann, W., G. Ericsson, and H. Dettki. 2011. The Impact of Human Recreational Activities: Moose as a Case Study. Alces 47:17-25.

Podruzny, S., S. Cherry, C. Schwartz, and L. Landenburger. 2002. Grizzly Bear Denning and Potential Conflict Areas in the Greater Yellowstone Ecosystem. Ursus 13:19–28.

Reed, S.E., J.P. Mann and J.L. Boggs. 2009. SPreAD-GIS: an ArcGIS toolbox for modeling the propagation of engine noise in a wildland setting. Version 1.2. The Wilderness Society, San Francisco, CA. http://www.acousticecology.org/docs/TWS_SPreAD_usersguide.pdf

Schwartz, M.K., J.P. Copeland, N.J. Anderson, J.R. Squires, R.M. Inman, K.S. McKelvey, K.L. Pilgrim, L.P. Waits, and S.A. Cushman. 2009. Wolverine Gene Flow Across a Narrow Climatic Niche. Ecology 90(11):3222–3232.

USDA Forest Service (FS). 2011. Forest Plan amendments for motorized access management within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones (Kootenai, Lolo, and Idaho Panhandle National Forests) USDA Forest Service Northern Region. Missoula, MT.

USDI Fish and Wildlife Service (FWS). 2008. Biological Opinion on the effects of winter motorized recreation Forest Plan Amendment for the Flathead National Forest" ("A24") on Grizzly Bears. U.S. Fish and Wildlife Service, Montana Ecological Services Field Office. Helena, MT.

USDI National Park Service (NPS). 2013. Yellowstone National Park winter use plan / supplemental environmental impact statement February 2013. Yellowstone National Park, WY. http://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

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Snowmobile Best Management Practices for Forest Service Travel Planning: A Comprehensive Literature Review and Recommendations for Management – *Winter Recreational Use Conflict*

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ABSTRACT: Winter wildlands are becoming increasingly crowded, and use conflicts are on the rise. To address use conflict and other resource impacts, the USDA Forest Service has begun Travel Planning in the snow-belt region. To assist in this process, this article presents recent research on how snowmobile use and associated noise and fumes impact non-motorized use. Motorized use often creates annoyance non-motorized users that has been documented to lead to displacement. However, a well-planned and enforced system of routes and areas, as well as improved management tools and technologies, has been shown to help reduce or eliminate conflict. Based on research and existing management strategies, we present a set of best management practices (BMPs) to address winter recreational use conflict and to create a more socially and environmentally sustainable system of motorized and non-motorized designations on National Forest lands.

Keywords: Travel planning, snowmobiles, best management practices, BMPs, winter recreational use conflict, USDA Forest Service

INTRODUCTION

As more people recreate in the backcountry, winter wildlands are becoming increasingly crowded, and conflicts are on the rise. Backcountry skiers and other non-motorized users seek solitude, quiet, and undisturbed natural areas. Desirable terrain, snow conditions and access are also key components of their recreational experience. Snowmobiles change the quality of this experience and create conflict with other winter recreationists (Adams and McCool 2012). Conflict among motorized and non-motorized use is typically "asymmetrical;" skiers experience conflict; snowmobilers do not (Knopp and Tyger 1973, Jackson and Wong 1982, Gibbons and Ruddell 1995). Quiet, non-motorized recreationists can have the quality of their experience dramatically altered by snowmobiles, while motorized users often don't even notice skiers using the same landscape. This article reviews how snowmobile use affects the soundscape, airshed, and viewshed of non-motorized users and presents management strategies for mitigating these impacts.

Soundscape

Protecting quiet soundscapes has become an increasingly important management issue in winter landscapes. Snowmobile noise is one of the biggest sources of use conflict, as an increasing number of winter recreationists seek the peace and quiet found in the backcountry as a way to escape the sounds of modern busy life (Abraham et al. 2010). Noise from motorized recreation is a particular problem in winter because all use becomes restricted to a relatively small number of plowed trailheads, thus significantly reducing access to wilderness for non-motorized users.

Research shows that natural soundscapes assist "in providing a deep connection to nature that is restorative and even spiritual for some visitors" (Freimund et al. 2009, pg. 4). When recreationists have these expectations, the mechanical noise of snowmobiles in otherwise quiet areas can result in a substantial diminution in non-motorized users' recreation experience. This often negatively impacts the experience of the recreationist, creates conflict, and ultimately leads to displacement (Gibbons and Ruddell 1995, Manning and Valliere 2001, Vittersø et al. 2004, Adams and McCool 2010).

In "multiple-use" backcountry areas, snowmobile noise can be difficult to escape. While dependent on speed, type of machine, and direction of wind, snowmobile noise can travel up to 16 km (10 mi; Hastings et al. 2006, Burson 2008) – a distance farther than most non-motorized recreationists travel in a day. Additionally, considering that most forest roads are not plowed in the winter, the ability of skiers to avoid motorized noises is very restricted. Often trails and areas that are considered "front-country" and easily drivable in the summer are much more difficult to access in the winter. Accordingly, the user expectation in these areas is more aligned with a backcountry experience including a quiet soundscape. This strong disconnect between available recreation settings and desired user experience is something the USDA Forest Service (Forest Service) primarily addresses in planning using the Recreation Opportunity Spectrum (ROS). However, ROS is a classification tool that describes physical, social, and managerial attributes – access, remoteness, size, user density, and level of development – in summer, but not winter. Addressing these front-country multiple-use areas, which span a variety of ROS settings and experience high user conflict, is a particularly important priority for travel planning strategies.

Many people also travel in the winter backcountry to view wildlife. However, it has been well established that noise has a widespread and profound impact on wildlife (Barber et al. 2010, Farina 2014), which limits opportunities for viewing and listening to birds and other wildlife. Most fundamentally, snowmobile noise creates annoyance for many non-motorized users that reduces the quality of backcountry experience and may lead to displacement (e.g., Stokowski and LaPointe 2000, Manning and Valliere 2001, Adams and McCool 2010).

Airshed

Motorized and non-motorized winter backcountry recreationists are often confined to the same plowed parking areas to prepare for their trips. However, in these "staging areas" snowmobile emissions can be concentrated and lead to an additional source of conflict and potential health concerns. While technological advances have produced cleaner four-stroke engines (and even zero emission electric snowmobile prototypes), the vast majority of snowmobiles still use highly polluting two-stroke engine technology. Lubricating oil is mixed with the fuel, and 20 to 30 percent of this mixture is emitted unburned into the air and snowpack (Kado et al. 2001). Also, the combustion process itself is relatively inefficient and results in high emissions of air pollutants (USDI NPS 2000). As a result, two-stroke snowmobiles emit very large amounts of smoke which includes carbon monoxide (CO), unburned hydrocarbons (HC) and other toxins (Zhou et al. 2010).

Concerns over human health related to snowmobile emissions have led to extensive recent research on snowmobile pollution in Yellowstone National Park (e.g., USDI NPS 2000, Bishop et al. 2001, Kado et al. 2001, Bishop et al. 2006, Bishop et al. 2009, Ray 2010, Zhou 2010), and conclusions from these studies have led to a Park ban of 2-stroke engines (USDI NPS 2013). Emissions from snowmobiles release many carcinogens and can pose dangers to human health (Eriksson et al. 2003, Riemann et al. 2009). Several "known" or "probable" carcinogens are emitted including nitrogen oxides, carbon monoxide, ozone, aldehydes, butadiene, benzenes, and polycyclic aromatic hydrocarbons (PAH). While most of the acute toxic effects of snowmobiles are limited to staging areas and parking lots, the smoke and fumes from snowmobiles on trails can dramatically reduce the quality of the experiences of non-motorized users along the trail as well.

Viewshed and other impacts

In addition to the sounds and smells of snowmobiles, the mere presence of snowmobiles on the landscape can degrade the experience of many non-motorized users. In just a few hours, snowmobiles can access almost any basin in the west and disproportionately consume a limited resource, powder snow. Slopes displaying dozens of "high mark" tracks can take away the natural beauty of the landscape for some. The deep tracks of snowmobile can also create a hazard for skiers navigating a downward slope, or the tracks can quickly "track out" a slope, rendering it completely un-skiable. Safety is also a concern, as there is the possibility of collision with a snowmobile, or the risk of a snowmobile triggering an avalanche from above. Alternatively, a snowmobile can diminish the sense of risk or wildness because they effectively reduce the real and perceived distance from safety (Adams and McCool 2010).

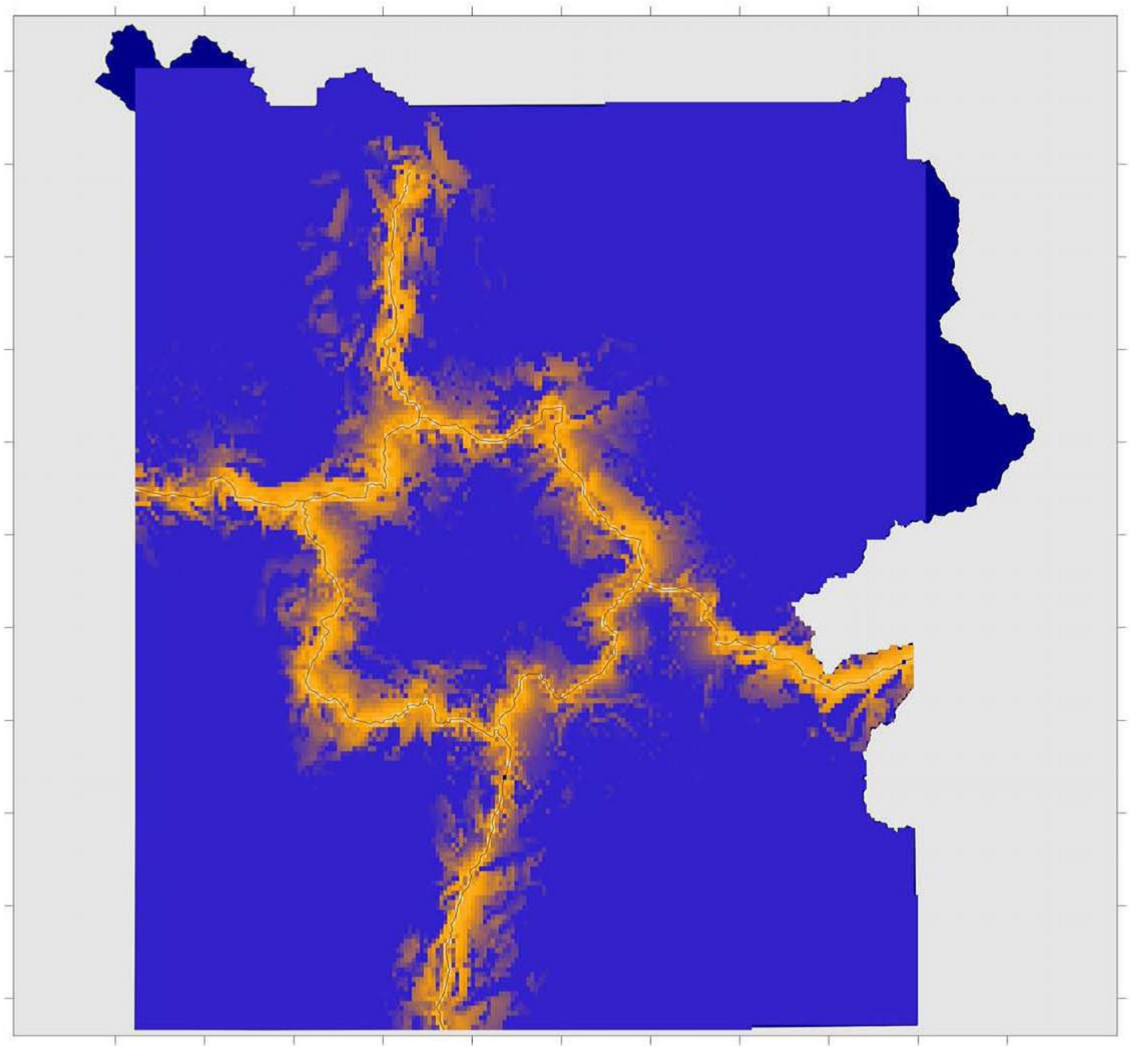
Winter recreational use conflict management

The most effective way to manage winter recreational use conflict is a well-planned and enforced system of routes and areas that separate motorized and non-motorized uses as much as possible (e.g., Andereck et al. 2001, Lindberg et al. 2009, Adams and McCool 2010, USDI NPS 2013). Simply reducing snowmobile noise and smells may not be sufficient to reduce conflict or deter displacement. However, limiting snowmobile use to best available technology (BAT) machines, as has been done at Yellowstone National Park, can substantially reduce use conflict. Closing or separating the non-compatible uses is the most effective way to reduce conflict. For example, an analysis of conflict reduction strategies in Sweden found that closing access to snowmobiles – a change from seeing, hearing, and smelling snowmobiles – led to significant skier welfare gains (Lindberg et al. 2009).

Another strategy employed by the Forest Service is to separate motorized and non-motorized temporally, thereby granting all users some opportunity for use while minimizing conflict. On the Chugach National Forest (AK), for example, one section of the forest is closed to motorized use on alternating years (USDA FS 2007a). On the Humboldt-Toiyabe National Forest (NV, CA), a high-elevation trailhead designated as shared use until lower elevation access receives enough snow for OSV use at which point it becomes non-motorized (USDA FS 2007b). In more popular areas, shorter alternating closure periods, such as biweekly, may be more appropriate.

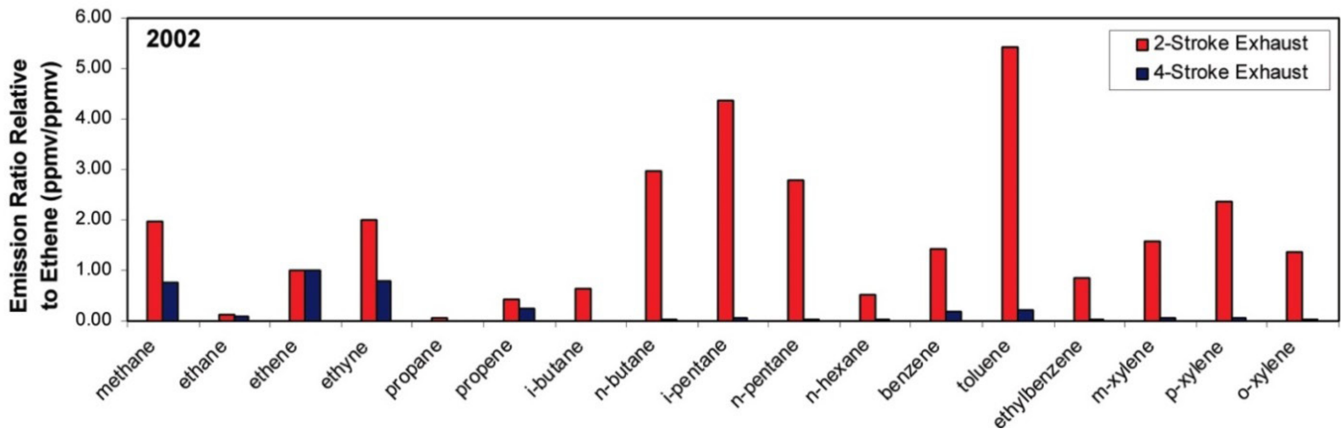
Mitigating snowmobile noise can also help address use conflict. Snowmobile noise can travel long distances in the winter, and noise models have been used to identify areas of recreational use conflict for management planning. For example, noise modeling has been used extensively in Yellowstone National Park to estimate the area affected by noise under a range of management alternatives (Hastings et al. 2006, Hastings et al. 2010, USDI NPS 2013, Figure 1).

Figure 1. Example of noise simulation modeling used in Yellowstone National Park to identify where disturbance and conflict may be a management issue. Orange is the distance snowmobile and snow coach noise travels beyond the groomed roads. Model inputs include temperature, relative humidity, snow cover, and natural ambient sound levels. The modeling also accounts for the acoustic effects of topography, vehicle speeds, and vehicle group size (USDI NPS 2013).



Several studies recommend replacing two-stroke engines with four-stroke engines to significantly reduce emissions and noise (e.g., Miers et al. 2000, Kado et al. 2001, Eriksson et al. 2003). Four-stroke engines are significantly less polluting (Zhau et al. 2010, Figure 2), and have improved fuel efficiency, as well as a reduction in visible exhaust plumes, odor, and noise (Bishop et al. 2006). A study of using best available technology (BAT) machines in Yellowstone has resulted in a 60% reduction in carbon monoxide (CO) and a 96% reduction in hydrocarbon (HC) emissions (Bishop et al. 2006).

Figure 2. Average non-methane hydrocarbons exhaust emission ratios relative to ethene (ppmv/ppmv) for two-stroke and four-stroke engines in 2002 (Reprinted with permission from (Zhou, Y., D. Shively, H. Mao, R.S. Russo, B. Pape, R.N. Mower, R. Talbot, and B.C. Sive. 2010. Air toxic emissions from snowmobiles in Yellowstone National Park. Environmental Science and Technology 44(1): 222-228. Copyright 2010 American Chemical Society).



However, if motorized use of a route or area has been identified as having an unacceptable impact on other user groups, that route or area should be closed (Lindberg et al. 2009, Adams and McCool 2010, and NYSDEC 2011). Furthermore, some National Forest lands have limited non-motorized recreation opportunities, so creating non-motorized areas may be needed. For example, a snowmobile plan for Adirondack Park (NY) calls for closing routes if the "opportunities for quiet, non-motorized use of trails are rare or nonexistent;" (NYSDEC 2011, p.244). Finally, in some areas – regardless of conflict – snowmobiling should not be allowed. For example, Adams and McCool (2010) argue that roadless areas should be protected from motorized use because "roadless areas are exceptional for their wild and quiet recreational opportunities, their habitat for threatened and endangered species, and other values. Their character and values derive from their lack of accessibility by motor vehicles" (p. 109).

To identify routes and areas that are sources of conflict, working groups have been established. However, for this collaboration to be successful, several key aspects have been identified, including: balanced stakeholder representation, clear goals and objectives, information exchange, and shared decision making (Schuett et al. 2001).

Best Management Practices for Winter Recreational Use Conflicts

Designating motorized use

1. When necessary elements for successful collaboration exist, establish a working groupwith motorized and non-motorized users, conservation interests, land managers, and other stakeholders to develop concepts for minimizing recreational conflict.
2. Identify routes and areas where conflict is ongoing among motorized and non-motorized winter recreational use utilizing existing information, surveys, GIS modeling, and community outreach.
3. Identify routes and areas of particularly high value or demand for motorized and non-motorized use.
4. To the degree possible, allocate separate trails, trailheads, and areas.
5. Ensure that non-motorized trails and areas are available:
    a. close to plowed access points, groomed trails, and other access portals.
    b. in contiguous non-motorized blocks.

c. in areas where there are few non-motorized opportunities.

d. in both frontcountry and backcountry settings.

e. in areas with scenic beauty.

f. in areas sheltered from noise emanating from motorized areas.

g. cross a variety of Recreational Opportunity Spectrum (ROS) categories.

6. Ensure that a fair balance of unplowed roads is set aside for non-motorized use.

7. Locate motorized routes and areas:

a. away from popular or historically used backcountry ski areas, or areas of growing use.

b. outside proposed Wilderness Areas, Wilderness Study Areas, and Research Natural Areas.

c. with easily enforceable boundaries using topographic or geographic features. (e.g., a ridge top or highway) - use boundary signage to provide additional clarity, or where unauthorized use is occurring.

d. where they do not bisect non-motorized areas.

8. Consider temporal restrictions in areas of high-use or high-value to both motorized and non-motorized use. This includes both early/late season restrictions, as well as alternating access.

9. Where necessary to designate a motorized route through a non-motorized area, locate and manage such route (such as speed and idling limits) to minimize disturbance to the non-motorized area.

10. In areas of shared use, consider requiring best available technology (BAT) to reduce conflict and impacts between uses.

Minimizing impacts of motorized use

1. Undertake proactive and systematic outreach programs in order to facilitate increased compliance of closures and reduce user conflicts.

2. Provide free digital and paper maps that clearly show routes, areas, and watersheds open and closed to snowmobiles.

3. Encourage or require the use of best available technology (BAT) snowmobiles to reduce noise and local air quality impacts.

4. Implement significant penalties and consequences for violating snowmobile regulations that will dissuade users from such violations.

5. Monitor closed routes and areas to ensure that snowmobile intrusion is not occurring.

6. Establish an adaptive management framework using monitoring to determine efficacy of current management.

7. Revisit plan decisions as necessary to ensure use conflicts are being minimized and motorized impacts are below accepted thresholds. Close snowmobile routes and areas when motorized use is leading to trespass onto non-motorized trails or areas.

CONCLUSION

The growing number of winter backcountry users has increased recreational use conflicts and negative impacts on natural resources. As the Forest Service begins formally addressing winter recreation and determining where motorized use is allowed, restricted, and prohibited, it is essential that managers have the best available science to guide their decisions. Snowmobiles can negatively affect the soundscape, airshed, and viewshed of non-motorized users. The most effective way to mitigate winter recreational use conflict is a well-planned and enforced system of routes and areas. Simply reducing snowmobile noise or smells can limit snowmobile impacts to non-motorized users, but may not be sufficient in reducing conflict. Rather, closing or separating the non-compatible users is the best way to reduce conflict. Collaboration among user groups can be successful, but there must be a balanced stakeholder representation, clear goals and objectives, information exchange, and shared decision making.

This document presented the best available science on the impacts of snowmobiles. Based upon this research and the recommendations of researchers and managers, and professional experience, we have developed a list of best management practices. These BMPs will help mitigate recreational use conflicts and minimize impacts to natural resources. Once a system of routes and special use areas is established, enforcement and monitoring will be critical to the success of any management plan.

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LITERATURE CITED

Abraham, A., K. Sommerhalder, and T. Abel. 2010. Landscape and Well-Being: a Scoping Study on the Health-Promoting Impact of Outdoor Environments. International Journal of Public Health 55:59-69.

Adams, J.C., and S.F. McCool. 2010. Finite Recreation Opportunities: The Forest Service, the Bureau of Land Management, and Off-Road Vehicle Management. Natural Resources Journal 49:45-116.

Andereck, K.L., C.A. Vogt, K. Larkin, and K. Frey. 2001. Differences Between Motorized and Non-motorized Trail Users. Journal of Park and Recreation Administration 10(3):62-77.

Barber, J. R., K.R. Crooks, and K.M Fristrup. 2010. The Costs of Chronic Noise Exposure for Terrestrial Organisms. Trends Ecology and Evolution 25:180-189.

Bishop, G.A., J.A. Morris, and D.H. Stedman. 2001. Snowmobile Contributions to Mobile Source Emissions in Yellowstone National Park. Environmental Science and Technology 35:2874-2881.

Bishop, G.A., D.A. Burgard, T.R. Dalton, D.H. Stedman, and J.D. Ray. 2006. Winter Motor-Vehicle Emissions in Yellowstone National Park. Environmental Science and Technology 40(8):2505-2510. http://www.nature.nps.gov/air/Pubs/pdf/yell/200604ESTBishop_etalSnowmobileEmissions.pdf

Bishop, G.A., R. Stadtmuller, D.H. Stedman, and J.D. Ray. 2009. Portable Emission Measurements of Yellowstone Park Snowcoaches and Snowmobiles. Journal of the Air and Waste Management Association 59:936–942. http://www.nature.nps.gov/air/Pubs/pdf/yell/Bishop_YELL_JAWMA59_Aug_936_2009.pdf

Burson, S. 2008. Natural soundscape monitoring in Yellowstone National Park December 2007– March 2008. National Park Service, Yellowstone Center for Resources, Mammoth, WY. http://www.nps.gov/yell/parkmgmt/upload/soundscape_monitoring-2007-2008.pdf

Eriksson, K., D. Tjarner, I. Marqvardsen, and B. Jarvholm. 2003. Exposure to Benzene, Toluene, Xylenes and Total Hydrocarbons Among Snowmobile Drivers in Sweden. Chemosphere 50(10):1343-7.

Farina, A. 2014. Soundscape Ecology - Principles, Patterns, Methods and Applications. Springer. Dordrecht, Netherlands.

Freimund, W., M. Patterson, K. Bosak, and S. Walker-Saxen. 2009. Winter experiences of Old Faithful visitors in Yellowstone National Park. University of Montana, Missoula, MT. http://www.nps.gov/yell/parkmgmt/upload/8_2009final_winter_experiences.pdf

Gibbons, S., and E.J. Ruddell. 1995. The Effect of Goal Orientation and Place Dependence on Select Goal Interferences Among Winter Backcountry Users. Leisure Sciences 17:171-183.

Hastings, A.L., G.G. Fleming, and C.S.Y. Lee. 2006. Modeling sound due to over-snow vehicles in Yellowstone and Grand Teton National Parks. Report DOT-VNTSC-NPS-06- 06, Volpe Transportation Center, Cambridge, MA.http://www.nps.gov/yell/parkmgmt/upload/finalsound%20_modelingreport.pdf

Hastings, A. L., C. Lee, P. Gerbi, G. G. Fleming, and S. Burson 2010. Development of a tool for modeling snowmobile and snowcoach noise in Yellowstone and Grand Teton National Parks. Noise Control Eng. J. 58: 591-600.

Jackson, E.L., and R.A.G. Wong. 1982. Perceived Conflict Between Urban Cross-Country Skiers and Snowmobilers in Alberta. Journal of Leisure Research 14(1):47-62.

Kado, N.Y., P.A. Kuzmicky, and R.A. Okamoto. 2001. Environmental and occupational exposure to toxic air pollutants from winter snowmobile use in Yellowstone National Park. Prepared for the Yellowstone Park Foundation and National Park Service.

Knopp, T.B., and J.D. Tyger. 1973. A Study of Conflict in Recreational Land Use: Snowmobiling vs. Ski Touring. Journal of Leisure Research 5(3):6-17.

Lindberg, K., P. Fredman, and T. Heldt. 2009. Facilitating Integrated Recreation Management: Assessing Conflict Reduction Benefits in a Common Metric. Forest Science 55(3):201-209.

Manning, R.E., and W.A. Valliere. 2001. Coping in Outdoor Recreation: Causes and Consequences of Crowding and Conflict Among Community Residents. Journal of Leisure Research 33(4):410-426.

Miers, S.A., R.D. Chalgren, and C.L. Anderson. 2000. Noise and emission reduction strategies for a snowmobile. Society of Automotive Engineers.

New York State Department of Environmental Conservation (NYSDEC). 2006. Snowmobile Plan for the Adirondack Park - Final Generic Environmental Impact Statement. Albany, New York. 67p.

Ray, J. D. 2010. Winter air quality in Yellowstone National Park: 2009-2010, Natural Resource Technical Report. National Park Service, Fort Collins, Colorado. http://www.nature.nps.gov/air/Pubs/pdf/yell/2009-2011_YELL_WinterAQ.pdf

Reimann, S., R. Kallenborn, and N. Schmidbauer. 2009. Severe Aromatic Hydrocarbon Pollution in the Arctic Town of Longyearbyen (Svalbard) Caused by Snowmobile Emissions. Environmental Science and Technology 43:4791–4795.

Schuett, M.A., S.W. Selin, and D.S. Carr. 2001. Making It Work: Keys to Successful Collaboration in Natural Resource Management. Environmental Management 27(4):587–593.

Stokowski, P.A., and C.B. LaPointe. 2000. Environmental and social effects of ATVs and ORVs: an annotated bibliography and research assessment. School of Natural Resources, University of Vermont. http://www.anr.state.vt.us/anr/atv_nov20_final.pdf

USDA Forest Service (FS). 2007a. Record of Decision. Kenai Winter Access, Chugach National Forest. 30p.USDA Forest Service (FS). 2011. Forest Plan amendments for motorized access management within the Selkirk and Cabinet-Yaak Grizzly Bear Recovery Zones (Kootenai, Lolo, and Idaho Panhandle National Forests) USDA Forest Service Northern Region. Missoula, MT.

USDA Forest Service (FS). 2007b. Decision Notice and Finding of No Significant Impact: Alpine Winter Recreation Project. Humboldt-Toiyabe National Forest. Alpine County, CA. 8p.

USDI National Park Service (NPS). 2000. Air quality concerns related to snowmobile usage in national parks. Washington, D.C.: Feb. 2000. http://www.nature.nps.gov/air/Pubs/pdf/yell/Snowmobile_Report.pdf

USDI National Park Service (NPS). 2013. Yellowstone National Park winter use plan / supplemental environmental impact statement February 2013. Yellowstone National Park, WY. http://parkplanning.nps.gov/document.cfm?parkID=111&projectID=40806&documentID=51874

Vittersø, J, R. Chipeniuk, M. Skår, and O.I. Vistad. 2004. Recreational Conflict is Affective: Case Study of Cross Country Skiers and Snowmobiles. Leisure Sciences 26:227-243.

Zhou, Y., D. Shively, H. Mao, R.S. Russo, B. Pape, R.N. Mower, R. Talbot, and B.C. Sive. 2010. Air Toxic Emissions from Snowmobiles in Yellowstone National Park. Environmental Science and Technology 44(1): 222-228.