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Winter Recreation Monitoring



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INTRODUCTION

This publication discusses techniques for monitoring winter recreation activity over vast areas. These techniques use commercial devices and airborne and spaceborne technologies as well as standard U.S. Department of Agriculture (USDA) Forest Service geospatial data sets and analysis tools. The information in this publication is useful to natural resource managers, recreation planners, landscape architects, or anyone who works with or wants to know about techniques to detect snowmobile activity on the landscape.

Several popular winter recreation activities occur on public land, including snowmobiling, skiing, snowshoeing, and snowboarding. This publication focuses on snowmobile activity because snowmobiles are designed to travel long distances, can be ridden off designated trails to access remote areas, and leave distinct tracks that are distinguishable from the air.

PROJECT BACKGROUND

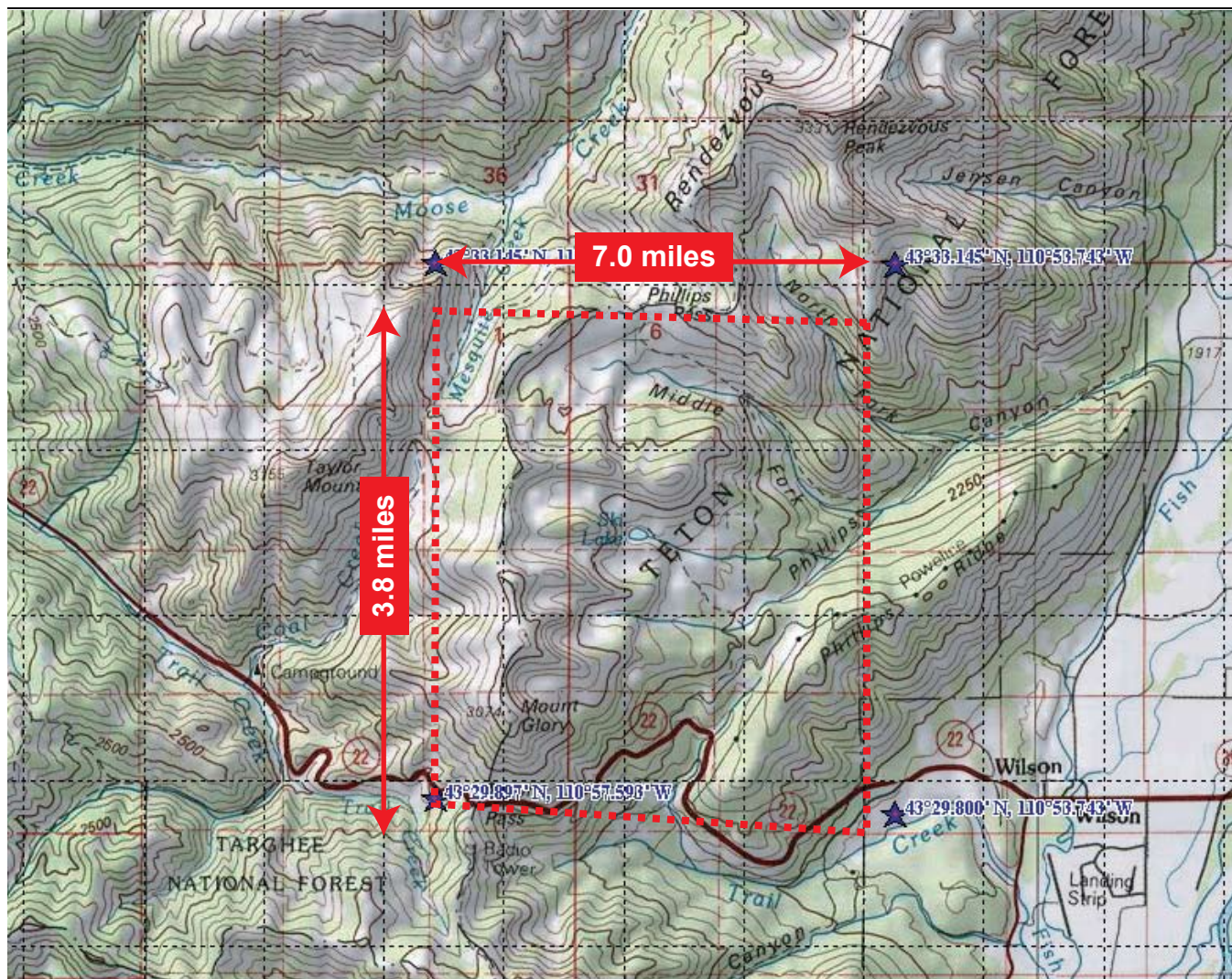
Technological advances allow snowmobiles access to places that were once unreachable by small-engine recreational vehicles. Magazines, snowmobile manufacturers, and tourism Web sites often describe the ease of accessing remote and isolated adventures away from designated trails. Unfortunately, on some national forests, snowmobile riders trespass into restricted and protected areas. Land managers are increasingly concerned about the effects of trespassing on wildlife populations, threatened and endangered species, and other resources. Ultimately, land managers need tools to predict and manage the effects of increased winter recreation activity on public lands.

APPROACH

Three central questions framed the approach and development of this project:

1. How can land managers determine the presence of winter recreation activity over a large area?
2. How can land managers detect winter recreation activity on the landscape using available technology?
3. How can land managers predict where activity may occur?

To answer these questions, San Dimas Technology and Development Center (SDTDC) staff selected a 26-square-mile study area to collect image data. The study area was located in eastern Idaho's Caribou-Targhee and Bridger-Teton National Forests near Teton Pass, north of Highway 22.



Project Area Location

Vertex	Latitude	Longitude
NW	43°33.145N	110°57.593W
NE	43°33.145N	110°53.743W
SW	43°29.897N	110°57.593W
SE	43°29.800N	110°53.743W

Figure 1. Study area.

With assistance from the USDA Forest Service Remote Sensing Applications Center (RSAC) in Salt Lake City, UT, SDTDC staff successfully collected digital photographs and satellite imagery to use to determine snowmobile activity in the study area. SDTDC developed use-pattern descriptors reflective of the landscape characteristics where snowmobile tracks were visible. By understanding the use patterns in an area of interest, one can develop a hypothesis of where winter recreation activity is likely to occur in other areas.

METHODOLOGY

A literature search resulted in four technologies that may help detect and monitor winter recreation activity. Two of these technologies, satellite imagery and aerial photography, are monitoring systems. The output from these two methods can be imported into geospatial and analysis software tools such as Environmental Systems Research Institute's ArcGIS and ERDAS Imagine.

The other two technologies, global positioning systems (GPS) and very high frequency (VHF) radio tracking are tracking systems. Tracking systems are discussed briefly in appendix A to provide alternative monitoring and detection methods but are not recommended for use over large areas.

SDTDC research found aerial photography and satellite monitoring cost effective and efficient tools for detecting and monitoring winter recreation activity. Aerial photography produced sharp images that enhanced the opportunity to detect more activity but only in a very small area. Satellite images are not as sharp but cover a much larger area with minimal cost.

MONITORING SYSTEMS

Satellite Imagery

Satellite imagery are photographs of the Earth or other planets taken from satellites orbiting in space. Satellite imagery has many applications and the potential to cover significantly larger areas than frame or digital photography.

SDTDC

Satellite-Imagery Application

Satellite imagery was tested to determine whether evidence of winter recreation activity was visible and to what degree. SDTDC used QuickBird images as its source for satellite images. SDTDC collected QuickBird imagery over a 3-year period. "The QuickBird satellite is the first in a constellation of spacecraft that DigitalGlobe® is developing that offers highly accurate, commercial, high-resolution imagery of Earth. QuickBird is currently the only

spacecraft able to offer submeter resolution imagery” (USDA Forest Service 2005).

SDTDC acquired the following geospatial data during satellite-imagery application testing.

- QuickBird Imagery
 - Winter 2003—Multispectral and Panchromatic (8-bit)
 - Winter 2004—Panchromatic (16-bit) See figure 2.

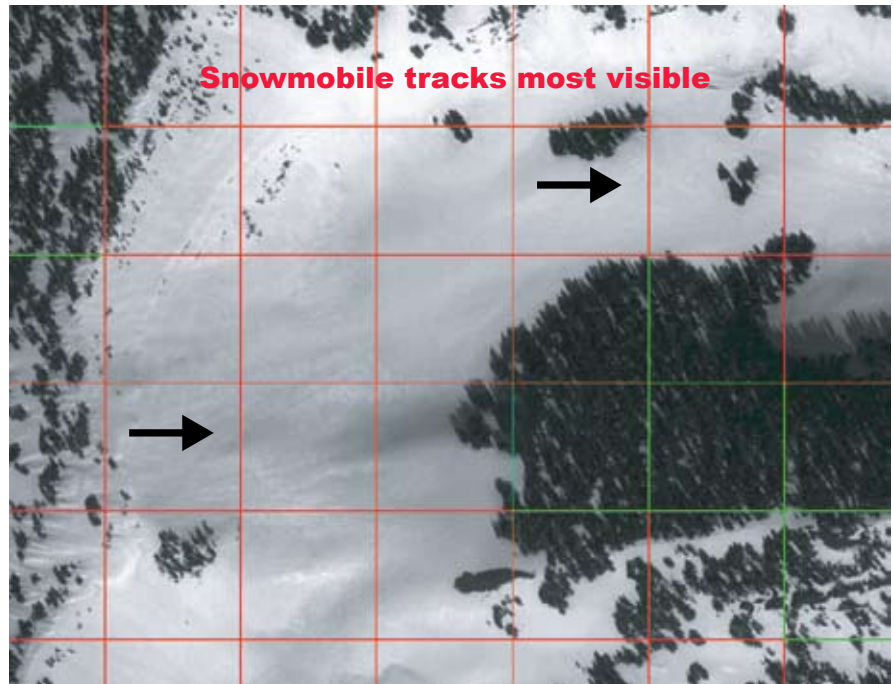


Figure 2—April 2004, Quickbird Panchromatic (0.7-meter, 16-bit)

- Winter 2005—Panchromatic (16-bit)
- Natural Color Digital Camera Imagery—Winter 2003
- Digital Elevation Model (10-meter)

SDTDC used RSAC’s staff to:

- Assess the utility of high-resolution satellite imagery for identifying snowmobile presence within national forest lands.
- Implement digital grid-cell analysis to determine the presence of snowmobile tracks.
- Investigate spatial correlation methods (ordinary kriging) to assist in characterizing the distribution of snowmobile tracks.

The first step in assessing the utility of high-resolution satellite imagery for identifying snowmobile presence within national forest lands was to conduct a digital grid-cell analysis. The analyses helped determine the use and location of recreation activity. A digital grid-cell layer was generated over the satellite images from 2003 and 2004. Each grid cell had a 5-acre cell size. RSAC staff assigned each 5-acre grid cell a unique code. Staff assigned “00” to cells without snowmobile tracks, indicating an absence of winter recreation activity, and “01” to cells with snowmobile tracks, indicating a presence of winter recreation activity. Ordinary kriging (see figure 3) was applied to help characterize the distribution of snowmobile tracks. Ordinary kriging is a geostatistical approach to modeling. Instead of weighting nearby data points by some power of their inverted distance, kriging relies on the spatial-correlation structure of the data to determine the weighting values.

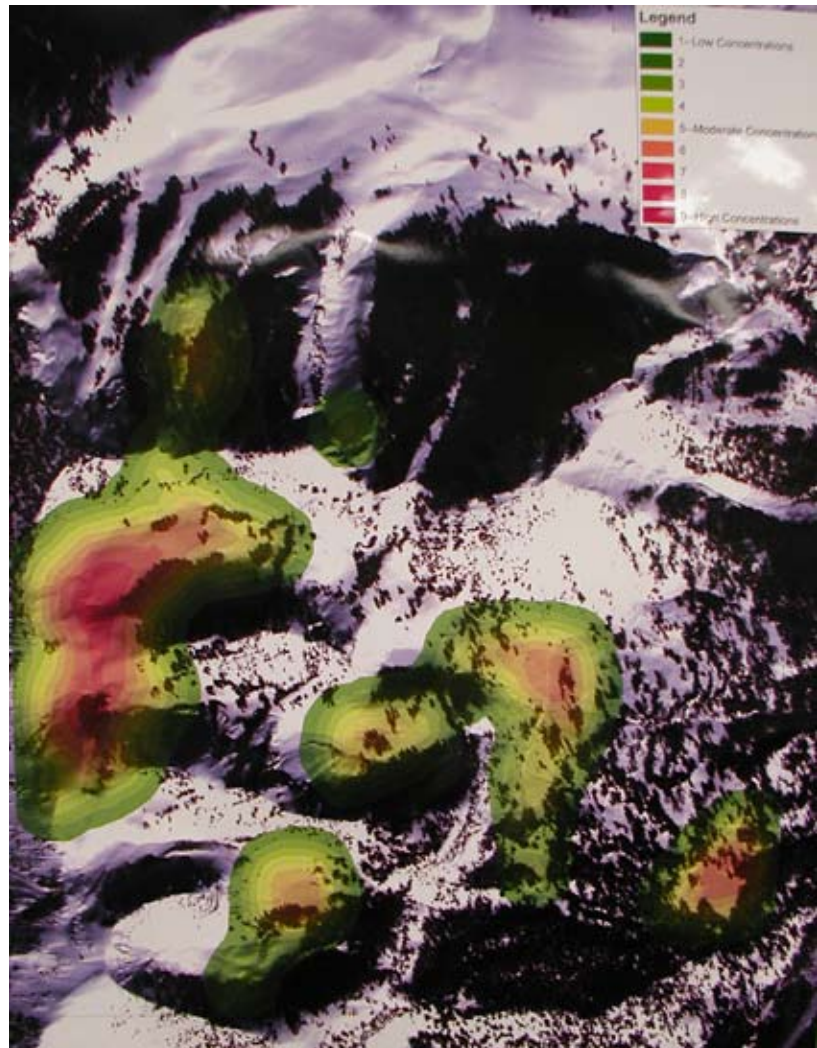


Figure 3—April 2004, Quickbird Panchromatic, Ordinary Kriging.

RESULTS

Snowmobile tracks are visible to some degree on all QuickBird satellite images. Based on the ability to identify snowmobile tracks, SDTDC staff ranked the imagery (from worst to best) as follows:

1. 2003 Panchromatic (0.7 meter, 8-bit) imagery (figure 4)
2. 2003 Multispectral (2.8 meter, 8-bit) imagery (figure 5)
3. 2004 Panchromatic (0.6 meter, 16-bit) imagery (figure 6)

The results indicate that increased radiometric resolution (8-bit versus 16-bit) equates to more resolving power. Spatial resolution (2.8 meter versus 0.7 meter) seems to have less influence on the ability to see tracks, but only until the resolution exceeds the typical 35- to 45-inch track widths.

The satellite-imagery application testing--using 16-bit or higher bit-depth panchromatic images--shows visible evidence of winter recreation activity. The test also demonstrated that digital grid cell analysis coupled with ordinary kriging is a viable approach for characterizing the distribution of snowmobile tracks.

Aerial Photography Methods

Aerial photography uses an aerial platform--typically an aircraft--to obtain photographs. The photos are taken at regular, spatial intervals and used in mapping and photo interpretation. Natural resource management uses aerial photography--in both digital and frame format--for many purposes and applications. Both formats have advantages and disadvantages depending on the desired results. Further discussion on these two formats is in appendix B.

Digital and frame photography can provide adequate resolution for use in remote sensing. Frame photography has the economical advantage of covering more area per photo than digital camera imagery with equal spatial resolution (RSAC 2002).

SDTDC Low-Elevation Aerial Photography Application Testing

Field-testing planned to answer two questions. First, how can land managers determine whether people are recreating in certain areas without relying primarily on ground truthing or direct observations? Second, what technology would determine successfully the presence and magnitude of winter recreation activity on the landscape?

SDTDC staff selected the study area in eastern Idaho. By using low-elevation aerial photography, staff acquired images of areas where winter recreation activity was known to have occurred



Figure 4—February 2003, Quickbird
Panhromatic, (2.8-meter, 8-bit)

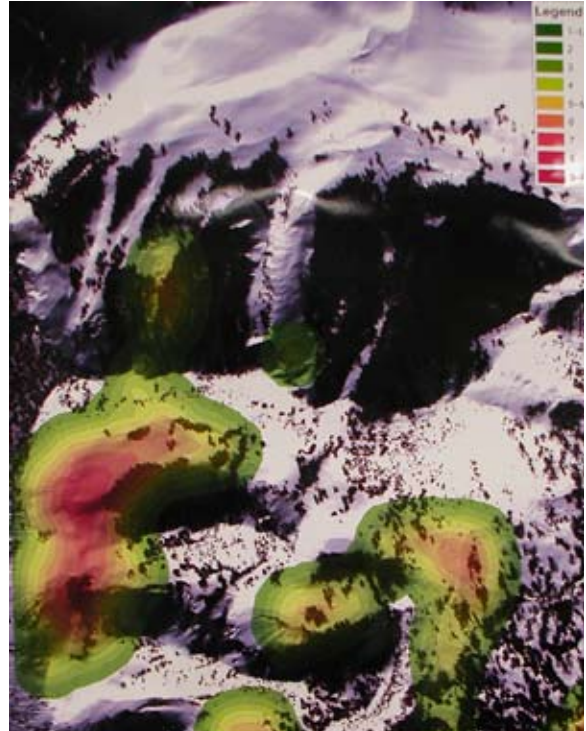


Figure 5—February 2003, Quickbird
Multispectral, (2.8-meter, 8-bit)

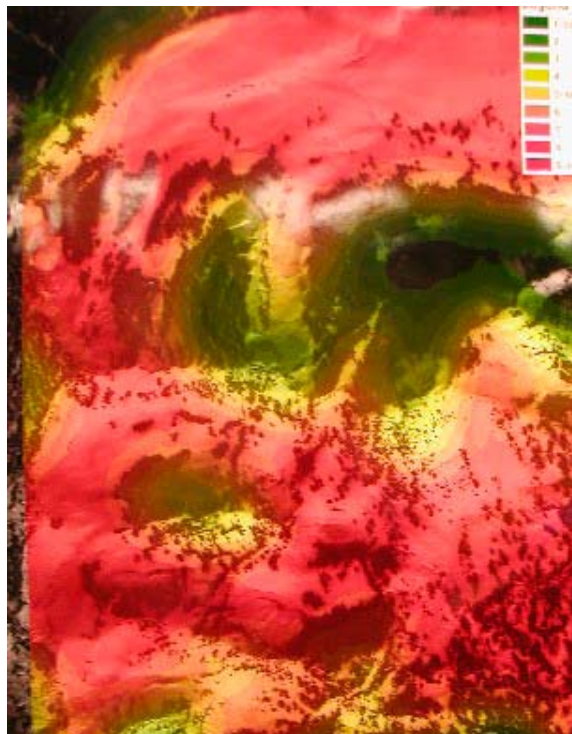


Figure 6—April 2004, Quickbird
Panhromatic, (0.7-meter, 16-bit)

recently. Using these aerial images, descriptions were developed of the areas where signs of winter recreation activity were evident. Describing winter recreation-use patterns and the associated landscape is known as developing “landscape descriptors” (see figure 7) and is the key component to predicting potential use areas in other locations.

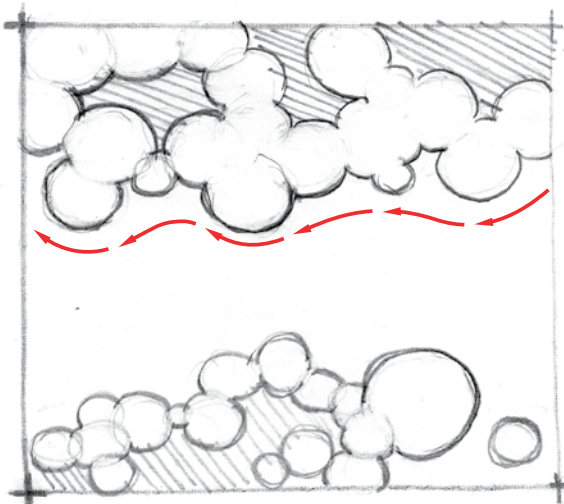
The photographic data suggests (see figure 8) that snowmobile activity was observed most frequently in large open areas and along long wide corridors framed by vegetation on both sides. The data also suggests that riders may be riding along ridge tops and parallel to the contour of a slope. This method of riding is known as “contouring.” Finally, the data suggests that some riders may spend time riding back and forth or in circles in the same area. These are called “play areas” and may offer some level of challenge to the rider. Play areas are often used for group play or to jump small terraced areas.

CONCLUSION

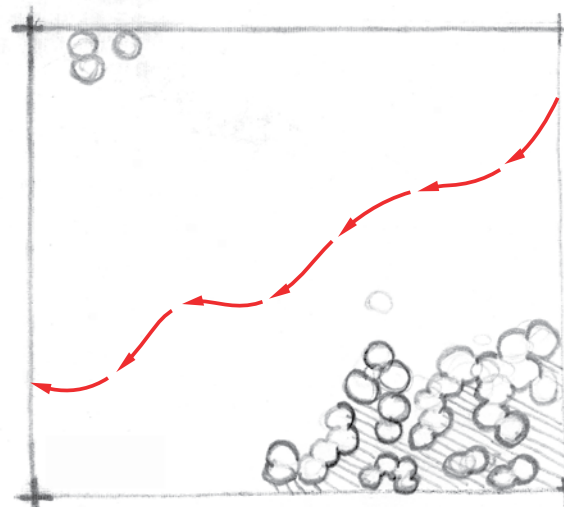
Land managers can determine recreation activity by using systems that monitor or track. Monitoring systems produce detailed information chronicling landscape characteristics and the location of recreation activity. Tracking systems offer the ability to locate individual riders or detect rider activity from a stationary position. Land managers can use aerial photography and/or high-resolution satellite imagery to determine winter recreation activity.

SDTDC used QuickBird satellite imagery and applied ordinary kriging to determine the extent of visible snowmobile tracks in the project area. After applying ordinary kriging to a variety of satellite images that were acquired at different resolutions and spectral ranges, snowmobile tracks were visible to some degree in all of the satellite images. Panchromatic images using 16-bit or higher bit-depth offered the best results. For finer detailed image data in a small area (1 square mile or smaller) either digital or frame aerial photography provides higher resolution than satellite imagery, and is therefore well suited for small-scale applications. Small-scale aerial images complement large-scale satellite images and provide image data for refined visual analysis—it is a matter of scale.

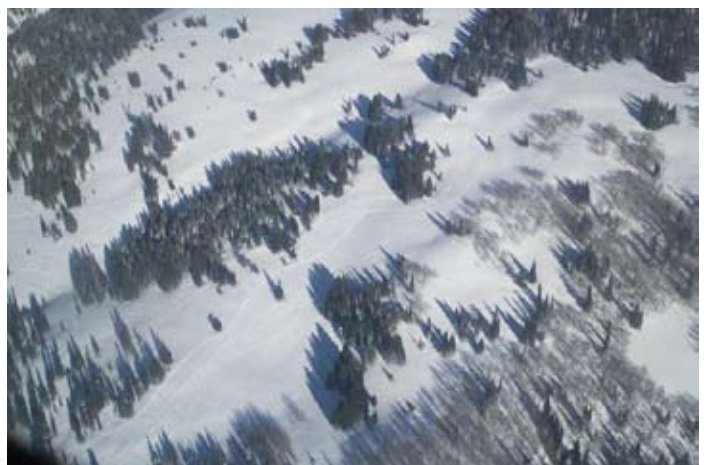
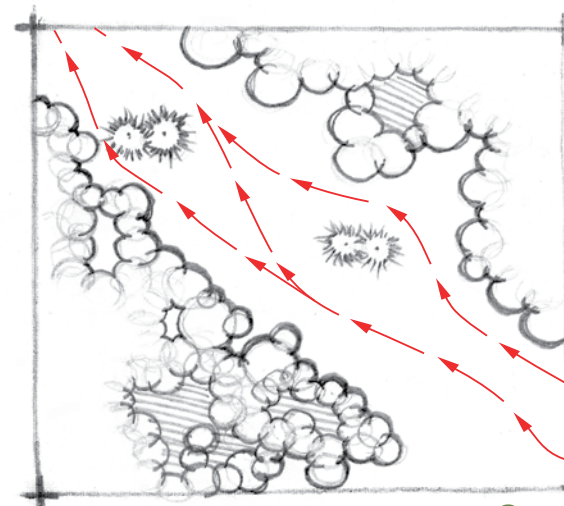
Land managers can predict where activity is likely to occur by developing specific landscape descriptors for the areas snowmobile operators frequently travel. Land managers can use either aerial or satellite images to develop these descriptors. By understanding the use patterns in a given area of the country, field units can develop a hypothesis of where winter recreation activity is likely to occur in other areas.



Hugging tree line.



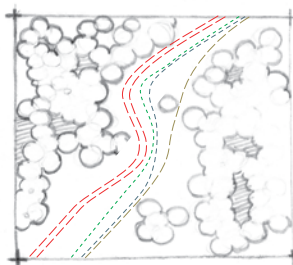
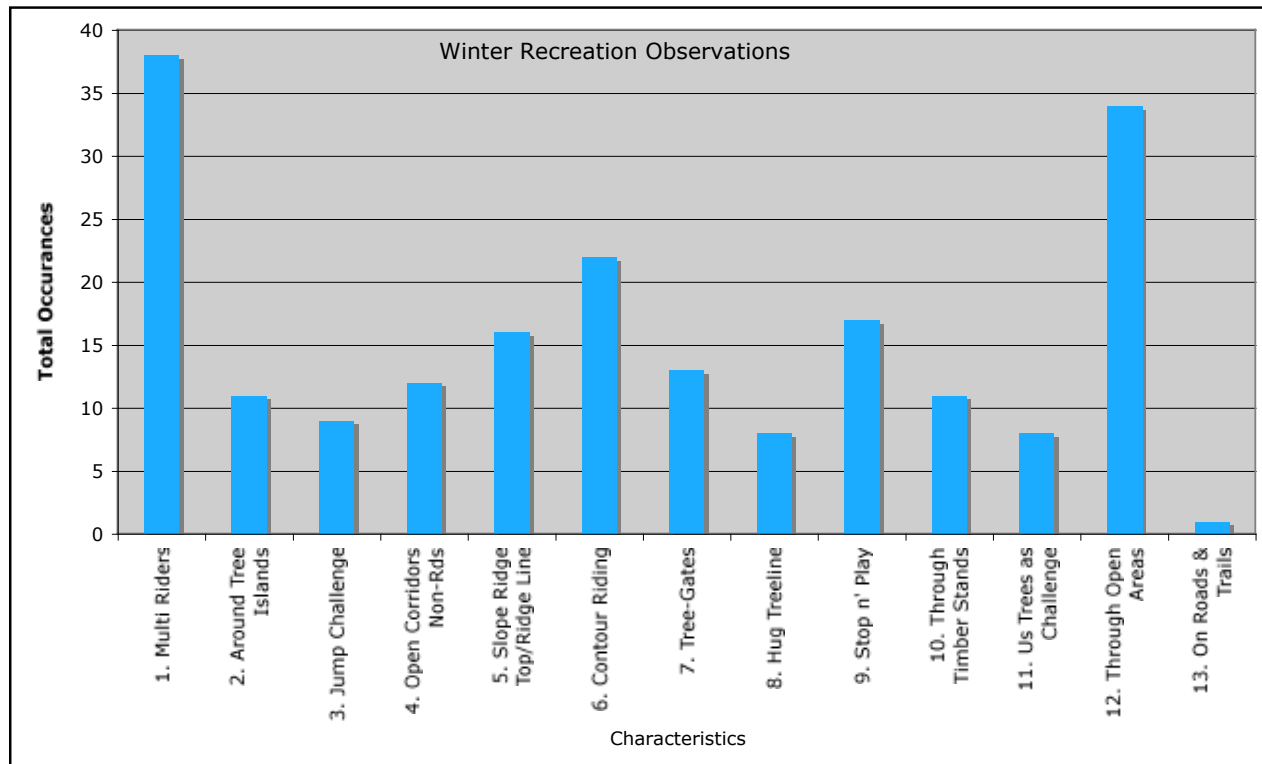
Through open area



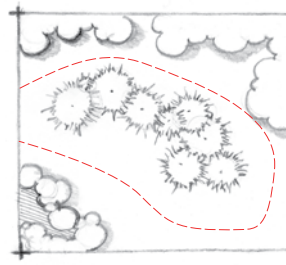
Open corridor

- Drainages
- Tree fingers

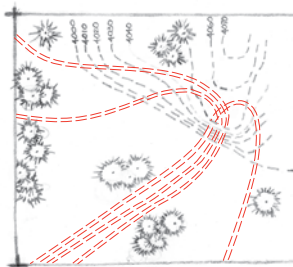
Figure 7—Landscape descriptors.



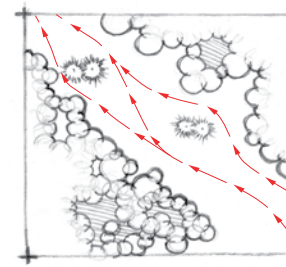
1. Multi-riders



2. Around tree islands



3. Jump challenges



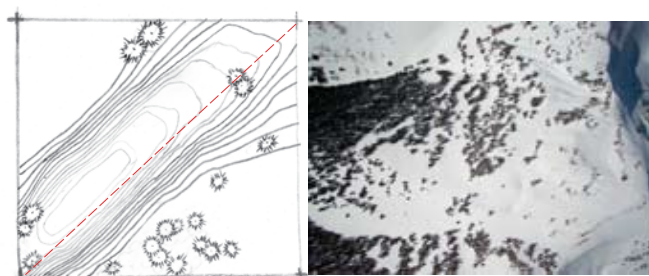
4. Open corridors non-roads



Figure 8—Winter recreation observations



5. Slope ridge top/ridge line



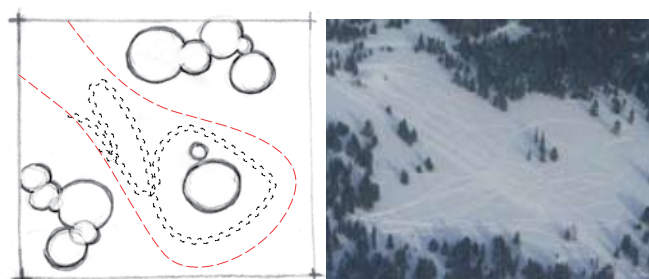
6. Contour riding



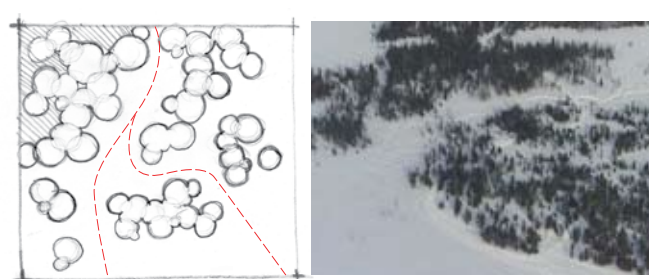
7. Tree-gates



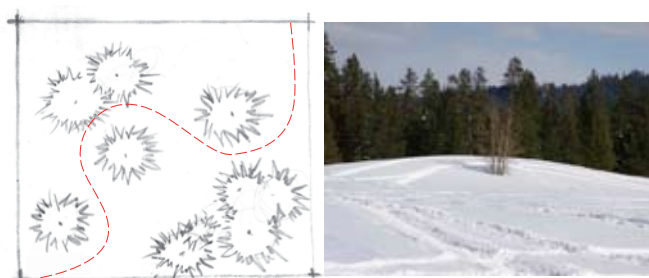
8. Hug treeline



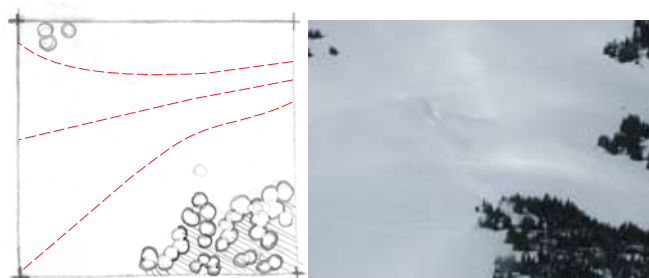
9. Stop n' play



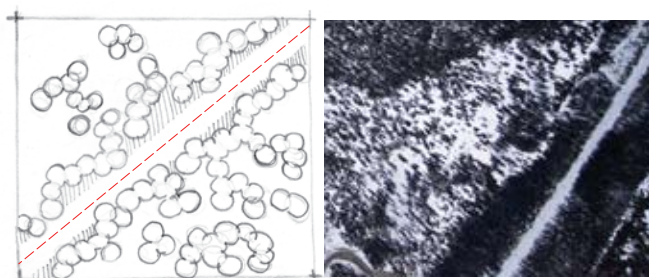
10. Through timber stands



11. Use trees as challenge



12. Through open areas



13. On roads and trails

Figure 8—Winter recreation observations continued.

After collecting and analyzing 3-years worth of image data the SDTDC winter monitoring study project found the following repeatable approach for monitoring and predicting winter recreation activity over vast areas:

1. Identify a study area.
2. Acquire low-elevation aerial images of the areas where the activity is known to have recently occurred. This may be an area other than or near the study area.
3. Use the newly acquired aerial images to develop specific landscape descriptors where signs of activity are evident.
4. Acquire high-resolution satellite imagery of the study area.
5. Identify areas on the satellite image that match the landscape descriptors acquired from the aerial images.
6. Conduct ground reconnaissance or low-elevation aerial photoreconnaissance of the areas identified on the satellite image.

Ultimately, understanding use patterns and identifying the terrain that attracts activity will aid in predicting where future winter recreation activity may occur on public lands.

APPENDIX A

TRACKING SYSTEMS

Two tracking systems can detect snowmobile activity. SDTDC did not test these tracking systems in the project area.

Global Positioning Systems (GPS) Technology

GPS is a satellite navigation system. It is designed to provide continuous accurate coverage throughout the world. GPS receivers are lightweight, easy to carry in the field, and able to acquire satellite signals under most field conditions. Under dense tree canopy the signal is often limited. Data from portable GPS receivers easily imports into a format compatible with geographic information system (GIS) applications.

Conceptually, GPS technology seemed to offer promising results in determining where snowmobile activity was occurring. SDTDC considered using GPS units to record the routes snowmobilers traveled. The idea was to record electronic track logs using GPS units attached to snowmobile riders. The track logs could later be displayed over a digital raster graphic forest map to see where the riders traveled. The logs could determine the exact sequence of events during the riders' travel, length of time a rider spent in an area, and individual riding habits. This information may help to establish the possible relationship between certain landscape characteristics and snowmobile activity. GPS technology in the context of tracking recreation activity is considered intrusive and potentially costly.

Radio Tracking Devices

VHF radio tracking is currently being used by natural resource managers to gather wildlife information through radio signals from a device carried by the wildlife. The device can send and receive data. According to a report by the U.S. Department of the Interior U.S. Geological Survey, the basic components of a radio-tracking system are a transmitting subsystem consisting of a radio transmitter, power source, and propagating antenna. A receiving subsystem includes a "pick-up" antenna, signal receiver with reception indicator (speaker and/or display), and a power source. Most radio tracking systems involve transmitters tuned to different frequencies (analogous to different AM/FM radio stations) that allow individual identification.

Using this technology to monitor snowmobile activity fails to provide resource managers with much data beyond the ability to identify individual riders and the ability to locate each rider when desired. This technology is intrusive and not practical in recreation settings.

APPENDIX B

DIGITAL AND FRAME PHOTOGRAPHY

Digital Photography

Digital photography uses a digitally encoded high-resolution image that is stored for later use. According to a report published by RSAC, digital cameras provide a unique capability to acquire high-resolution digital imagery over small areas in near real-time. Digital cameras are used successfully in situations when timelines and compatibility with commercial georeferencing software is critical.

Digital camera imagery advantages:

- Digital format (easy integration with computer software).
- No film processing (quick delivery).
- Compact (single unit).
- Low light-level imaging possible.
- Color-infrared band available.
- Greater dynamic range than conventional film camera systems.

Digital camera imagery disadvantages:

- Small area coverage because of small imaging surface size or charged coupled device array.
- Small footprints increase difficulty in locating common tie points for georeferencing.
- Moderate-size projects require:
 - Many images.
 - Significant digital storage space.
 - Manipulation of images that increases cost.

Frame Photography

Frame (film) photography produces object images on photosensitive surfaces. According to a report published by RSAC, frame photography is the standard remote sensing tool because of its wide range of applications. Vast amounts of aerial photography resources are available for national forest lands, resulting from the acquisition of resource photography.

While most resource photography is acquired with a 6-inch focal length lens, RSAC recommends an 8 1/4-inch lens. This allows greater flying height without compromising scale and reduces radial displacement of trees that would otherwise obscure trails (RSAC 2002).

Frame photography advantages:

- Large coverage with high spatial resolution.
- Available in a variety of scales.
- Available in a variety of formats (35 millimeter, 70 millimeter, 9 by 9 inch, and 9 by 18 inch).
- Available in several emulsions (black and white, black and white infrared, natural color, and color infrared).

Frame photography disadvantages:

- Analog (requires scanning the hard copy photographs to get them into digital format).
- Time required to get product.
- Requires precise color infrared exposure (narrow exposure latitude).

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U.S. Department of Agriculture, Forest Service. 2005. Satellite and imagery acquisition handbook—v.1. Manual. RSAC-2999-MAN1. Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, Remote Sensing Applications Center. The image acquisition guide is available in PDF format on the Remote Sensing Application Center Intranet at <http://fsweb.rsac.fs.fed.us/>.

