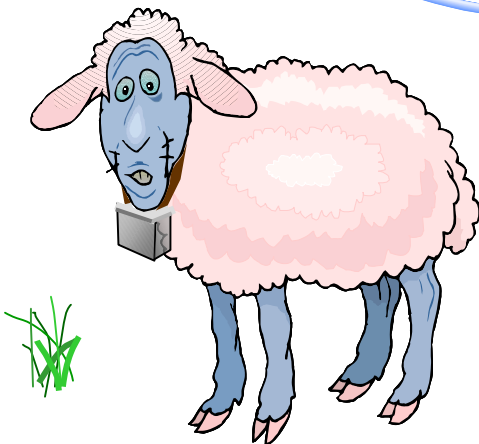
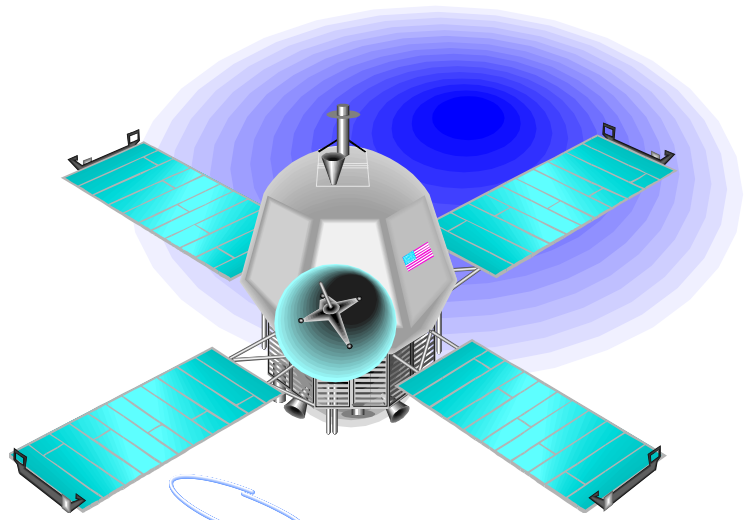


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Tracking Movements of Domestic  
Sheep with the Global  
Positioning System – an  
Application for Public Land  
Managers.



*by:*

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# **Tracking Movements of Domestic Sheep on Forest Service Grazing Allotments With The Global Positioning System A Demonstration Project**

A core objective of most allotment management plans on public lands administered by the U.S. Department of Agriculture (USDA) Forest Service is the movement and use of permitted livestock to achieve the resource objectives desired, and/or prevent conflicts with other uses. However, monitoring and documenting livestock movements and use through a grazing season is expensive and difficult, typically requiring several field reviews by qualified resource specialists. This demonstration project evaluated the use of the Global Positioning System (GPS) to achieve these monitoring objectives on sheep allotments.



The cost, size, and accuracy of GPS have all converged in recent years to make their use for tracking animal movements practical. During the summer of 2001 movement of a herd of sheep grazing in the Smiley Creek Sheep Allotment within the Sawtooth National Recreation Area (NRA) in Idaho, was recorded using the GPS\_2200L datalogger. Two sheep within the band were collared. The very high frequency (VHF) /GPS datalogger collars are designed and sold by Lotek Wireless Inc. of Ontario, Canada. This report addresses the procedures and success of applying the technology. The underlying science of GPS is not presented.

Both collars performed without compromise for 128 days between early June and mid-October, 2001. Ninety-four percent of the position attempts were successful over the period despite the mountainous and forested conditions. Launching and retrieving the data was less than intuitive, as with many new technologies; but once understood, the process was effective. The final data product includes animal positions, which are date and time stamped throughout the grazing season.

The two collars were launched with different sampling frequencies—every 2 hours with one, and every 4 hours with the other. Although a finer temporal resolution provides greater route detail, further analysis will be required to determine if the added detail is meaningful for day-to-day allotment management. Memory capacity of the collars could have easily accommodated an even-more-frequent sampling.

## **BACKGROUND**

Understanding the use and movement of permitted livestock across public lands administered by the USDA Forest Service is a core objective of numerous allotment management plans. The purpose of the animal movement is to achieve the resource objectives desired, and/or prevent conflicts with other uses. Yet monitoring and documenting such use have always been expensive and difficult, typically requiring specific field reviews by qualified resource specialists. Consequently, such monitoring typically falls short. Monitoring is particularly difficult with sheep allotments, given the wide migration routes and tight herding (i.e. it is difficult to know where they are, let alone where they may have been, and for how long).

With the recent protection under the Endangered Species Act (ESA) of four fish species found within the Sawtooth National Recreation Area, additional grazing use and movement objectives were added to allotment plans. Obligations and accountability to monitor have also substantially increased. In direct contrast, however, available personnel, time, and finances to meet these requirements have declined. Attempts to seek assistance from the livestock permittees have seen limited success. Although the herders are generally very familiar with the land, they are



typically unfamiliar with the use of maps and written documentation. In this context, then, the Sawtooth NRA investigated the use of GPS tracking technology to address the monitoring questions of, “where did they go, and when, and how long did they stay?”

Through correlation of such information with observed landscape conditions on the ground, the Sawtooth NRA hopes to gain greater understanding of the success or failure of the grazing strategy to achieve resource objectives.

## Features of the Unit Tested

The Lotek GPS\_2200L collar integrates a VHF beacon transmitter with a GPS datalogger and sensor. The collar was designed for use primarily in tracking mid-sized wildlife such as deer, wolves, bears, and large cats. An “R” version is available, which differs only in its smaller battery (and duty cycle) and overall size. The unit tested was a modified version of the “L,” referred to as an “L(R),” which has a rechargeable lithium-ion battery in a slightly larger housing. (See table 1.)

*Table 1—Specifications of Lotek GPS\_2200 collars.*

Specifications		Model	
		GPS_2200R	GPS_2200L(R)
Housing Dimensions (cm)	Length x Width x Height	12.0x8.6x10.5	12.0x8.6x12.6(14)
Belt Weight (g)	Heavy Duty; e.g., wolf	800-850	900-950
	Light Duty; e.g., deer	750-800	880-920
GPS Battery Life	Total #,of Fixes	4000	9000
	@8 Hour Fix Schedule	365 days	> 2 years
VHF Beacon Life		> 2 years	
Data Storage Capacity	Nondifferential	10,423 locations	
	Differential (optional)	5,028 locations	
VHF Range (frequency hardwired when assembled)		140 to 220 MHz	
Operating Temperature Range		-30 to +50 °C	
Data Retention Range		-50 to +75 °C	
Optional Sensors		Temperature, Mortality, Recovery, 2-Axis	

	Activity
Field Replaceable Battery Pack	Yes
Field Programmable	GPS & Beacon Schedule, Mortality Delay
Field Upload	GPS & Beacon Schedule, Satellite Almanac, Mortality Delay
Field Download	Data & Diagnostics

Key hardware features of the tested GPS\_2200LR include:

- VHF Tracking Beacon—The collar emits a beacon, which facilitates tracking and collar retrieval using conventional tracking techniques. The beacon also indicates the status of the collar by emitting a variety of pulse rates for different conditions (e.g., normal, dead battery, recovery, mortality). Beacon broadcast frequency is user specified and hardwired at the time of assembly.
- Battery—The lithium-ion battery is rechargeable and field replaceable. A fully charged battery is capable of recording up to 9,000 position fixes, for over a 2-year period, depending on the frequency of position fixes.
- Data Storage—The capacity for data storage is more than 10,000 position fixes.
- Housing—The housing is made of high-impact resin, with high tensile strength, and high and low temperature resistance. The unit is waterproof to a depth of 10 meters.
- Collar—The collar integrates the GPS antenna into an adjustable strap. The antenna itself sits, nonprotruding, on the top of the collar strap for maximum signal exposure. The belt is foam padded and adjustable from both sides to center the antenna.
- Electronics – The unit's operational temperature range is from -30° to +50° C (which is better than that of the sheep).

The following options are available to customize the units:

- “Activity” Sensor (not tested)—The two-axis activity sensor detects and records “active” verses “resting” animal states.
- Temperature Sensor (not tested)—The temperature sensor records ambient air temperature.
- Differential Correction (not tested)—The differential correction collects and records position fixes so that accuracy can be further improved through post-processing. (It also requires an operational base station and additional Lotek N4WIN software.)
- GPS Scheduler—This scheduler allows modification to the default frequency of position fixes. A “basic” scheduler (tested) allows a single change to the default frequency of position fixes (e.g. every 4 hours or every 2 hours through the period). The “advanced” scheduler (not tested) allows extensive control with scheduling position fixes (e.g. every 30 minutes from 8 a.m. to 8 p.m., and every 2 hours from 8 p.m. to 8 a.m., or every 2 hours from June 1 - August 1 and every 4 hours from August 1 to October 1).
- VHF Beacon Scheduler (not tested)—This scheduler allows modification to the default beacon operational schedule (i.e., 8 a.m. to 5 p.m.).

- Programmable Mortality Setting (not tested)—The programmable mortality setting allows modification to the default mortality delay (8 hours); (i.e., animal time at rest before transmitting the mortality/recovery signal).

The unit requires the use of Lotek software (GPS\_2000 Host). The MS-DOS-based software accommodates the full options and sensors available with the GPS\_2200 unit. With the included cables and “download link unit”, the software facilitates launching the units, and subsequent retrieval of the data. The download link is battery powered (rechargeable) to facilitate downloads to a laptop in the field.



Table 2—Cost of Lotek collar as tested (GSA, August 2000).

Product	Cost	Finally, the package as tested also included all the tools and products for successful deployment including recharge kit, O-rings, sealant, special screws, and even a torque nut driver. (See table 2.)
GPS_2200L(R) Collar (each)		
(includes basic GPS_2000 Host software)	\$2,328	
Recharge kit	\$97	
Download link	\$728	
Torque nut driver	\$165	
Basic scheduler	\$291	
Total	\$3,609	

## SETTING FOR THE TEST

The Sawtooth National Recreation Area in central Idaho was created in 1972 from National Forest lands, and remains the largest NRA in the National Forest System. It was created “to assure the preservation and protection of the natural, scenic, historic, pastoral, and fish and wildlife values and to provide for the enhancement of the recreation values associated therewith” (PL 92-400). Grazing of permitted livestock on public lands continues in accordance with the management objective of “providing for consumptive uses of resources including . . . grazing . . . so long as these uses do not substantially impair the recreational and associated values for which this recreation area was established.”



The Smiley Creek Sheep Allotment is located at the headwaters of the Salmon River, in the southern end of the Sawtooth NRA, within the Sawtooth Valley. The allotment includes 41,435 acres (16,768 hectares) of broad glacial trough and outwash valleys, bisected by parallel



mountain ridges. It encompasses all or part of the Vat, Cabin, Alturas, Beaver, Smiley, and Frenchman Creek watersheds.

Vegetation is made up of conifer trees (primarily *Pinus contorta*) on slopes and ridges, sage/grass/forbs in the open valley bottoms, and willow lining the streams. Elevations within the allotment range from 6,500 to more than 10,000 feet (1,980 to more than 3,050 meters). Perennially flowing streams are the norm within the allotment, although the summer of 2001 continued an unusually dry climatic period.



In 2001, the livestock permittee of the Smiley Creek Allotment was authorized to graze 870 ewes with lambs between June 7 and August 28. Lambs were removed and shipped on August 28, at which time the remaining band was supplemented with another 530 ewes, for a total of 1,400 sheep. These sheep continued to graze the allotment until trailing began on October 12.

## RESULTS

### Preparation

In anticipation of the test, one of the collars was tested for a 3-week period in March and April 2001 at the U.S. Sheep Experiment Station in Dubois, Idaho. The purpose of the test was to compare the GPS\_2200L(R) collar with a prototype backpack harness unit. Concerns had been raised by experiment station staff regarding the durability of the collars, given the head-down grazing habits of sheep. Following this brief test, concerns were reduced and the station staff recommended the Sawtooth NRA proceed with the full test as planned, using the collars. The backpack prototype had its own particular challenges (G. Lewis, station manager, personal communication).

Before deploying the collars, the GPS\_2000 Host software had to be loaded onto a standard PC, and configured for the particular computer and geographic location. A current satellite almanac was downloaded from Lotek's Web site just before deploying the collars. The almanac is required to inform the collar of the approximate locations of available satellites upon its first fix attempt. After this first fix, this information is communicated automatically from the satellites to the collars. Finally, the approximate geographic location of the deployment site was entered—again, to assure a quick and successful first fix.



A link with the collar was established and the position and almanac information, as well as the schedule for position fixes, was sent to the collar. The first fix must be obtained within 10 minutes or the VHF beacon will switch into "Recovery" mode.

## Deployment



The Lotek GPS\_2200L(R) collars were fitted on two randomly selected sheep as they were off-loaded from the livestock shipping trucks. The permittee used a shepherd's crook to select and control the sheep. The collar strap was quickly looped around the animals' necks and secured with holding plates and lock nuts tightened to the specified 1.7 N·m torque. The collars were adjusted on both sides to center the antenna on top. The sheep were marked with colored chalk to distinguish them within the band, and then were released.

## Active Use

The Sawtooth NRA did not possess a VHF receiving antenna and assumed it could monitor the sheep by visual observation during allotment administration. The agency arranged to borrow an antenna from a sister agency if needed. Within a week, one of the collared sheep was missing. An antenna was obtained and the ewe was shortly found with a broken leg. The "recovery" beacon pulse was never heard, suggesting she continued sufficient movement to maintain the "normal" beacon.

No other problem was encountered. The chalk quickly wore off, and the VHF antenna was the only means to monitor the status of the sheep and their collars. The VHF antenna also proved to be a very effective tool in monitoring the band location, whether nearby and visible, or more distant. If visual identification is important, a more durable product, such as marking paint, may be required.



The effect of fleece growth through the season on the fit of the collar was a speculated concern initially, but proved to be of no consequence. The collar remained snug on the neck, and the fleece accumulated around it. No interference with the satellite signal was apparent.

Incidentally, the sheep's leg was likely broken during the permittee's scuffle to capture and constrain the sheep initially to attach the collar. The herder had noted the sheep limping as she walked away after the collar was attached. Care in such occasions is obviously important to avoid injury to the animal as well as to the handlers.

## Retrieval



The collars were collected without difficulty on October 12 by the permittee. Close inspection of the collar straps and unit housings found no compromised conditions beyond normal wear. In contrast to some pretest concerns, the collars appeared to be very durable.

The process to retrieve the data from the collars was a reverse of the initial launching. Once connected to the PC through the download link unit, the data was collected from both collars without incident.

## Post Processing

The data was exported from the Lotek GPS\_2000 Host software to a Microsoft Excel® spreadsheet. Once in Excel, the data was corrected, analyzed, and prepared for further analysis in the Geographic Information System (GIS).

The Lotek collar stores latitude and longitude positions in degrees, minutes, and decimal seconds (to thousandths). When exported from the host software via the spreadsheet option, the values are converted to integer milliseconds. (See table 3.)

*Table 3—Sample of the core data as exported from the GPS\_2000 Host software.*

Latitude	Longitude	Height	Date	Time	DOP	Fix Status	SAT ID
158111287	-413337179	2167	6/7/2001	8:00:35	2.4	3D Fix	02 04 05 07 09 24
158082353	-413349224	2187	6/7/2001	10:00:39	2.7	3D Fix	04 05 06 10 24 30
158083601	-413356270	2184	6/7/2001	12:00:49	2.3	3D Fix	06 10 15 17 24 30
158086535	-413361563	2184	6/7/2001	14:00:36	4.3	2D Fix	06 15 17
158076787	-413350297	2184	6/7/2001	16:00:41	1.4	2D Fix	03 14 15 18 21 23

To prepare the data for analysis within the GIS the millisecond latitude and longitude values were converted to decimal degrees by dividing the milliseconds values by 3,600,000 (60 minutes x 60 seconds x 1000). (See table 4.)

*Table 4—Sample of the Latitude and Longitude conversions performed in the spreadsheet.*

Latitude millisecond	Latitude decimal degrees	Longitude millisecond	Longitude decimal degrees
158111287	43.91980194	-413337179	-114.81588306
158082353	43.91176472	-413349224	-114.81922889
158083601	43.91211139	-413356270	-114.82118611
158086535	43.91292639	-413361563	-114.82265639
158076787	43.91021861	-413350297	-114.81952694

Simple formatting and heading changes were then also applied to a few of the remaining fields for compatibility with the GIS. The result was saved in dBase IV® format.

ArcView GIS® version 3.1 was used to create a geographic theme for analysis from the table of position values (i.e., an “Event Theme”). For compatibility with the Sawtooth National Forest corporate GIS data themes (e.g., roads, streams, lakes), the new collar themes were reprojected. Once the export position format of the GPS\_2000 Host software was understood, this relatively straightforward export process was completed and field maps produced for grazing use correlation within a day.

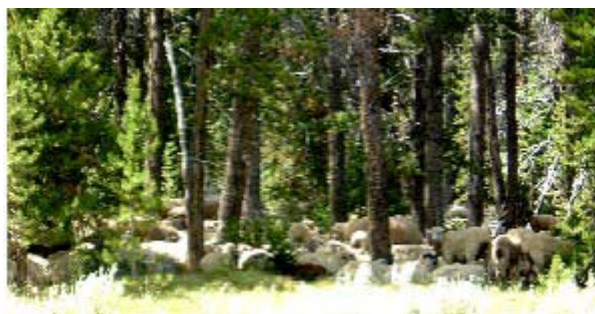


## DATA SUMMARY

Beyond the one broken leg, no influence to the well-being of the sheep wearing the collars was ever observed. The herders never expressed concern, and in fact, seemed genuinely interested in the technology. For the purpose of the test, the information was not intended to be applied to 2001 allotment permit administration, but only in the use and utility of the technology.

Over the 128 days between early June and mid-October 2001, the sheep fitted with the collars traveled 232 miles (373 kilometers). Their routes depict a slow, deliberate circulation through the allotment—up and down drainages, and ascending and descending several ridges. Nearly half of the total grazing season was spent between 7,000 and 7,500 feet (2,134 and 2,286 meters) on the valley floor, and less than 5 percent above 9,000 feet (2,743 meters).

The two collars attempted 2,288 satellite position fixes over the duration of the test. Of these, 94 percent were successful. When a failure occurs, the collar records a descriptor of the most likely cause. Of the causes listed, the lack of at least three satellites was the most common, followed by the threshold for dilution of precision (DOP—basically the uncertainty in position resulting from the particular geometry of the satellite constellation) being exceeded. Over the test period, failures were most common in July. On a daily basis, failures were most common during the late morning to afternoon period. It can be speculated that both of these tendencies are related to overhead obstructions (i.e., trees). When trees were more dominant in the landscape, position failures were more common. Day to day, sheep seek shade during the peak heat periods, and generally bed in the open during the night. The most successful fix periods of the day occurred at night between 10:00 p.m. and 4:00 a.m. (See table 5)

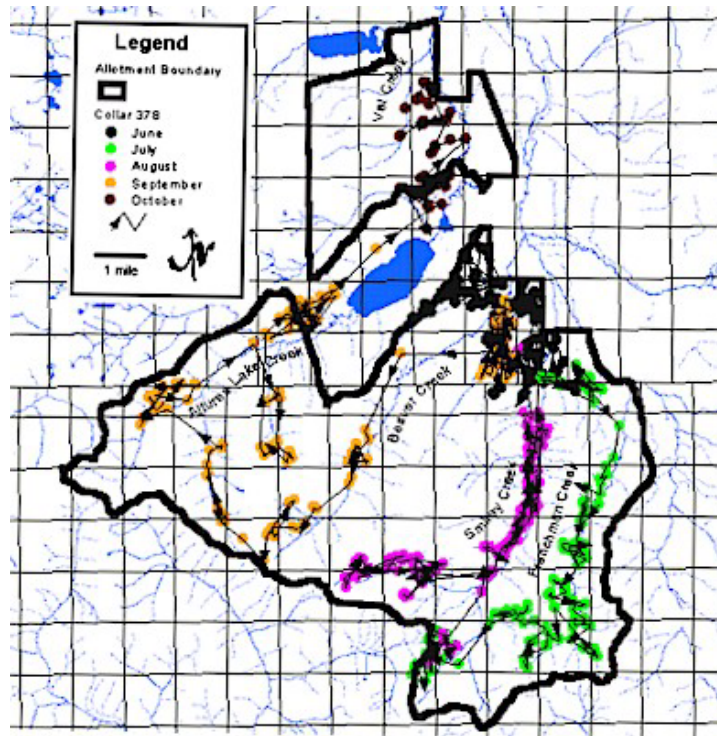


*Table 5—Summary of position fix success*

Collar	378	379
Fix frequency	4 hours	2 hours
Total attempts	763	1,525
Total successful	709	1,431
Percent successful	93	94
Percent of memory Capacity used	8	15

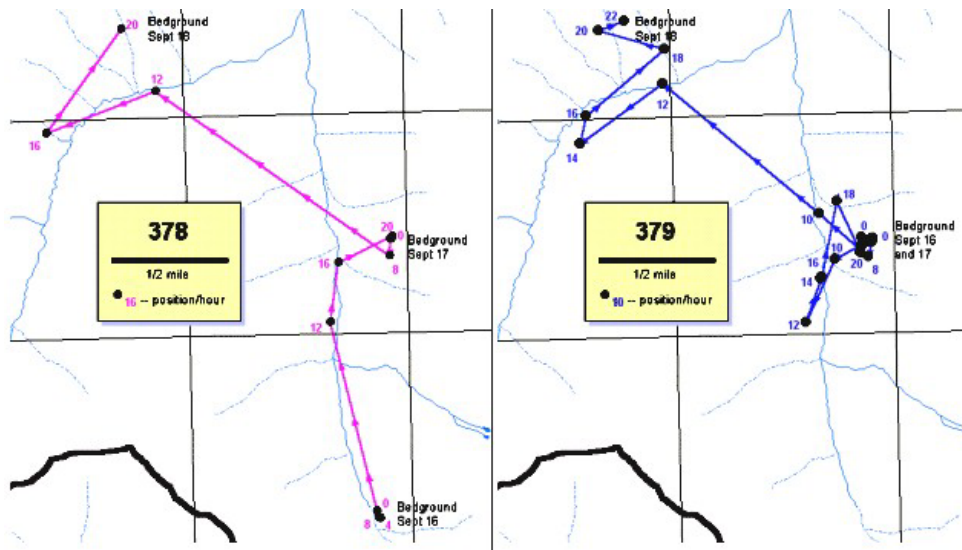
Some subtle differences between the individual sheep wearing the collars may be evident in the data. The sheep wearing collar 378 appears to have routinely ascended higher when grazing ridge-tops, and was quicker to enter mid-day cover than the sheep wearing collar 379. The grazing habitats of neither sheep appear to have had any effect on the integrity of the collars. Post-inspection of the collars revealed nothing beyond expected scuffs and scratches on the external case. (See figure 1.)

Figure 1—Collar 378 full season GPS position results.



The only difference tested between the two collars was the sampling frequency. The results are a matter of fractal resolution. The path of the sheep wearing collar 379, which sampled at twice the temporal resolution of collar 378, would appear to wander to a greater extent than did 378. In fact, for the full season, the plotted route of collar 378 is 176 miles compared to 232 miles for collar 379, or only 76 percent. This difference, however, is more likely a simple expression of the greater temporal resolution of collar 379. Figure 2 displays comparative routes recorded by the collars during September 16 and 17, 2001. These dates are a random example, with the exception that all position fix attempts were successful for both collars over the 48-hour period.

Figure 2—Comparison between position sampling frequencies of Collars 378 (4 hour) and 379 (2 hour).



The example in Figure 2 demonstrates both the natural variation between animals, as well as the more detailed route of collar 379 with the greater temporal resolution.

## **Conclusions**

As had been hoped, the collars proved manageable, durable, and informative. No compromise of the data occurred. A 94 percent position fix rate was surprising, given the mountainous terrain and widespread conifer forest within the allotment. Position fixes at 2-hour or even 4-hour frequencies seem sufficient for general allotment management objectives; however, the memory capacity of the collar could have held data equivalent to sampling every 20 minutes over the same period. Also, rather than being just an emergency utility in case a sheep was lost, the VHF beacon proved to be very helpful for routinely locating the sheep. The greatest challenge was understanding and facilitating the downloaded data into analysis and display tools.

For land managers, extended review and analysis of such data may provide a greater understanding of grazing use levels as they relate to achieving resource objectives. The information also provides the ability to respond to monitoring obligations. For the permittee, the information may provide the means for evaluating and improving herding routes and practices to enhance profits.

## **ACKNOWLEDGMENTS**

Several individuals contributed to the successful implementation of this test. Brenda Land of the San Dimas Technology and Development Center, reviewed the proposal, researched and located the Lotek collars, financed one of the collars, and facilitated the publication of this paper. Greg Lewis, and his staff of the U.S. Sheep Experiment Station provided crucial assistance with sizing the collars for sheep; they also provided a brief pretest of the collars. John Faulkner willingly provided his herd of sheep for the test, and assisted with launching and retrieving the collars. Tina Ruffing, Sawtooth NRA Range Technician, provided the day-to-day administration and coordination for the collars. Gary Gadwa, conservation officer with the Idaho Department of Fish and Game, graciously loaned his VHF tracking antenna for several weeks to assist with locating and monitoring the sheep. Leadership of the Sawtooth National Recreation Area, Debora Cooper and Becky Nourse, willingly provided the priority for their staff to see the test through. Adrian Gyulay and others of Lotek Wireless Inc. and Rob Daley, GIS specialist Sawtooth National Forest, provided valuable guidance with the post-processing of the data. The authors acknowledge these invaluable contributions and appreciate the assistance.

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