Assess Feasibility of Using GPS Collars to Study Remote Populations of Desert Bighorn Sheep
Maze District
Canyonlands National Park
Utah

Funded by CNHA Discovery Pool Grant
Contract # 06-2-NPS

William B. Sloan
National Park Service
2282 S. West Resource Blvd.
Moab, UT 84532

February 3, 2009

Introduction

Widespread population declines and local extinction during the past century eliminated bighorn sheep (*Ovis canadensis*) from most of their historic range in the western United States. When the Maze District was added to Canyonlands National Park in 1971, the native bighorn sheep herd had been extirpated from the area. In January 1982, 23 bighorn were translocated from the Island in the Sky District's herd and released on the northeast side of the Maze District. Population numbers remain low, and impacts from increasing recreational use, long-term drought, and other environmental factors remain unknown.

The Maze District of Canyonlands National Park covers 73,000 acres to the west of the Green and Colorado Rivers and is the most remote district of the park. Monitoring the sheep population there on the ground has always been difficult due to the extreme remoteness of the area and to logistical constraints. In addition, monitoring from the air has been extremely difficult because of the rugged, convoluted nature of the terrain. For these reasons, the Maze population of bighorn has received less attention than the other populations in the park.

A radio-collared bighorn sheep ewe. Photo by William Sloan

This project was proposed in order to determine whether state-of-the-art GPS (Global Positioning System) collar technology can be used effectively in remote canyon terrain to provide specific data on desert bighorn sheep ecology. In September 2006, a $15,000 Discovery Pool Grant was awarded to the National Park Service by the Canyonlands

Natural History Association (CNHA) to assess the feasibility of using these collars to study remote populations of bighorn sheep in the Maze District. Without a helicopter and contract capture team to deploy the collars in 2007, the project was postponed until 2008.

Research Needs

Traditional VHF radio collars have been used successfully on some sheep herds to establish habitat use, range, lambing areas, and population dynamics. Use of these radio collars necessitates either flying with a transceiver to collect realtime location data or hiking in to areas occupied by the collared animals to get the data. Typically, flying is expensive, and collecting data by hiking is limited to accessible terrain somewhat near a road system. Furthermore, because use of this technology results in only realtime readings of animal locations, not many data points can be collected.

GPS-enabled collars have the potential to provide less expensive and more extensive data collection on sheep populations in remote areas. Because data retrieval is accomplished via a special receiver through the VHF signal output by the collar, the sheep do not have to be recaptured to download data, reducing stress on the animals as well as expense. In addition, a High Speed Transmission (HST), downloadable during certain hours of the day, gives up to 400 data points rather than just realtime location data.

However, the rugged terrain of the canyon country may present challenges for using this promising technology. This project was needed to test the feasibility of using sophisticated GPS technology to provide essential data on bighorn sheep: habitat preferences, travel corridors, lambing areas, predation, and population dynamics, all important factors in managing for long-term viability of desert bighorn sheep on public lands.

In order to assess the feasibility of using this technology, both GPS signal acquisition and multipath errors needed to be determined. A GPS satellite signal must be received in order to record location data. For that data to be accurate, it cannot be distorted by bouncing off cliff walls or uneven terrain.

Methods

Six GPS collars were purchased from HABIT Research, LTD. at a cost of $1675 each from other funds. These collars were represented by the company to give location data accurate to within five meters and have a battery life of up to three years. The most recent GPS data received by these collars was designed to be transmitted via the VHF signal every minute to give realtime location data. In addition, the most recent 400 GPS fixes were to be sent through the High Speed Transmission (HST) feature between the hours of 10:00am and 1:00 pm, MST, downloadable with the HABIT Research Osprey HR2600 Data Telemetry Logger Receiver, which had been purchased in advance from other funds for $2255. These HST transmissions were to be sent every 15 minutes for the three-hour window. A three-element Yagi directional antenna was also purchased from HABIT, and the cost was included in the purchase price of the collars.

Upon delivery, the Osprey receiver was malfunctioning and had to be returned to the manufacturer, as the signal strength would not exceed the 2% level. Unfortunately, it was not returned from the company in time to field test the collars before deployment, despite assurances from the company that it would be.

Sheep capture and collaring was accomplished by hiring a contract crew and helicopter at a total cost of $9000, with this expense being paid by the Discovery Pool Grant. The collars, set to collect and record GPS location information four times per day, were attached to captured sheep in the Maze District in January 2008. Because data storage capacity for each collar was approximately 100 days, downloads were attempted once every four weeks for ten months. At the time of capture, blood draws and throat swabs were performed on each animal to facilitate testing for disease.

Attempts to download the data from overflights, funded through the NPS Fee Demo program, commenced in March. Six flights were conducted through November, but efforts to download the HST proved futile. Two to four hours of flight time were used on each flight, attempting to download the HST while circling 800 feet above the satellite collar. Persistent equipment failure triggered an adjustment in our methods. To improve data reception, we purchased the recommended three-element Yagi antenna, but that did little to help.

The receiver, Yagi antenna and GPS collar used in the project. Photo by William Sloan

The receiver continued to experience problems, including the speaker cone being inverted after being returned again from the company and greatly reducing sound quality. After further suspected software problems, the receiver was returned again to the manufacturer; newer HST (High Speed Transmission) software was installed and the unit retested, but data reception was not improved. However, for the purposes of VHF reception, the receiver was fully functional.

Although attempts to download the GPS data were unsuccessful from the overflights, each collared animal's VHF signal transmitted on a different frequency, allowing us to determine the location of each individual. This location information was layered with existing GIS themes to show seasonal movements, habitat utilization, overlap with recreational users, lambing areas, movement corridors, and potential barriers to movement.

At the end of this study, the collars were left on the sheep. It is anticipated that data from the collars will provide some valuable information for another two or three years, as determined by battery life. That data will be incorporated into the long-term monitoring program conducted by the National Park Service.

Results

Once the collars were in place on the animals and the receiver in hand, efforts to download the GPS data from lofty overlooks up to 21 kilometers away proved futile, even though the VHF signals were audible. Similar attempts to collect the data from much closer locations, requiring extensive hiking, likewise failed, during a four-day foot survey in the Maze, and three four-day river trips. For instance, with some animals being visible and within 900 meters of the receiver, only sporadic and usually incomplete data were received.

Due to the failure of the HST feature to function as advertised, the desired extensive data set was not obtained that would have provided the essential location data for each collared animal. However, the limited data that was obtained through the tracking of VHF signals, combined with the small amount of data manually downloaded from two collars recovered from dead sheep, did provide some valuable information on the home ranges of the animals.

Six aerial telemetry flights have been completed as of this writing. Extensive time has been taken on each flight circling 800 feet above the GPS collars between the specified HST times of 10:00 am to 1:00 pm, MST. Only sporadically has complete GPS location data been received, despite using the receiver correctly. Usually, incomplete or garbled data has been all that was logged. Never has a HST been received, despite 10 hours of flight during the correct hours, the proper use of the equipment, and a seemingly functional receiver. Fortunately, the VHF signals were received from each animal during the flights, thereby determining each animal's realtime (or current) location and range.

In numerous other instances of actual observation, results again were inadequate. While observing GPS-collared animals from distances ranging from 200 meters to 900 meters, only sporadic, outdated and usually incomplete data were received, despite an adequate radio signal and clear reception. Once again, the receiver was operated properly by the very experienced operator.

Of the six GPS collars, to this date only two have received and transmitted the latest received GPS data on several occasions. #839 and #098 have both occasionally shown complete GPS data, but the data has always been outdated rather than current. #082 once, on September16, displayed complete GPS data; it, also, was old, dated from July 22. Coincidentally, #839 also had received its last data on July 22, and this also was transmitted and displayed on the September 16 overflight. This fact seems to indicate this was the last date the collars were able to receive any information from the satellites. Collar #250 also displayed current GPS data once in April. The other two collars, #149 and #201, still appear to have never received any GPS data, since no new data has ever been received, transmitted and displayed, and likely have failed completely in their GPS capability. If the GPS collars and satellites were aligning and functioning properly, the new GPS data should have been updated and displayed every minute.

Two of the collared animals died during the course of the project, and the GPS collars were retrieved, presenting an opportunity to download stored data and test the collars and receiver in a controlled, close-range experimental setting.

#098 last received new data on April 22. It was located in the same spot for two overflights, leading me to believe it was a mortality, or dead animal, even though the mortality signal (a double signal pulse) was not activated. I retrieved the collar on August 6, buried in a foot of flood debris in a wash above the river. No carcass was associated with the collar, and, disappointingly, the mortality feature on this collar had not worked. Subsequent and numerous attempts to effect a HST from this collar at close range and in a controlled environment failed. A test collar (requested from the manufacturer), however, situated next to it, performed the HST download with no problem. A manual full data dump was finally employed to retrieve what data #098 had stored onboard. Approximately 250 GPS data locations were downloaded from when the collar was on the animal. Of these, only 23 were valid GPS locations of where the animal actually was. The rest were false locations. For instance, the longitude of 109.899333 was recorded on 108 dates, over a span from January 31 through April 22. These locations were obviously in error, as it placed the animal seven miles away from its range, across the river, and in non-sheep habitat. An additional 118 latitude and longitude locations were redundant and inaccurate. Multipath errors, caused by the satellite system's signal bouncing off of cliff walls, apparently created distortions in the GPS locations in these instances. In addition, all received and stored data, erroneous or not, was received by the collar between 11:09 and 11:12 am, instead of at the planned six hour increments, indicating a problem with the internal clock within the satellite collar. The clock had been set by the manufacturer prior to shipping.

The collar #250 had not moved all summer from the location observed in April, which was the only occasion any current GPS locational data was displayed. Five telemetry overflights found its VHF signal located in the same restricted valley, where permanent water is not available. Although the mortality signal on this collar, like that of #098, had not been activated, the lack of movement indicated this animal was deceased and the collar needed to be retrieved. Aerial reconnaissance during the telemetry flights did not reveal any way into or out of the valley, and it appeared even the surefooted ram had trapped himself in, getting down but not being able to get back out. The retrieval of the collar required a 70 meter rappel into the valley; the collar and carcass were found in the wash near a dry waterhole.

A risky manual data dump was required to access what information was stored onboard #250 in the radio memory, since the High Speed Transmission feature did not function, even at close range. (A manual data dump puts any stored data at risk of unrecoverable loss). The data that was retrieved was disappointing. Of 262 fixes from February through the end of April, when the animal died, only 53 were valid GPS locations, accounting for an approximate 20% success rate. The rest were false or redundant data. All locations during this time were received by the collar at the times of 18:33, 18:56 or 18:57, with the resulting redundancy of locations. For instance, on February 28, 42 incorrect "fixes" were obtained between 18:33:20 and 18:33:44. As with collar #098, many locations revealed significant multipath errors, and it appeared on this satellite collar also that the internal clock had not been set correctly at the time of manufacture, or had malfunctioned.

A test collar was requested and received from the manufacturer. This collar was not transmitting at full strength, by admission of the manufacturer, but its HST capability remained intact. At times I needed to be within 147 feet of the collar for the receiver to display a GPS location during controlled tests. However, I was able to consistently download the GPS data through the High Speed Transmission feature at the correct times. The other collars, however, retrieved from the dead animals #098 and #250, never performed the HST function, although placed at the same range as the test collar. In addition, the #098 collar was monitored throughout its 12-hour duty cycle in case the internal clock was in error, but the HST function never came on. A second receiver was also requested and received from the manufacturer. When tested alongside the original receiver, results were similar, but the original receiver actually had better reception. Both received the HST data from the test collar, but neither did from the retrieved #098 collar. The same was later true when collar #250 was retrieved and tested at close range.

Collar #098, retrieved from the dead ewe, did have 23 correct locations over a ten-week period. These locations revealed the range of this ewe to be in an area that ewes had not previously been known to inhabit. Although the 23 correct locations were less than 10% of all locations recorded on this collar (the rest had been in error), the correct locations still represented more data than would have been obtained through ground observations or aerial telemetry. Collar #250 had 53 correct GPS locations in a 12-week period, for a near 20% success rate, once again supplying more efficient locational data than aerial telemetry would have provided in this amount of time.

Additionally, the capture effort funded by this project provided an opportunity to test the animals for disease by drawing blood and taking throat culture swabs. After capture, the animals were treated for the *psoroptes* mite. Results of the testing are as follows:

Infectious Bovine Rhinitis (IBR) – Five of the animals showed no significant titers, but #250 tested positive for exposure.
Bovine Viral Diarrhea 1 & 2 (BVD) – All animals tested negative for both, showing no significant titers.
Bovine Respiratory Syncytial Virus (BRSV) - All animals tested negative, showing no significant titers.
Parainfluenza–3 (PI-3) (Shipping fever) – An antibody response was shown on all six animals. Five of them tested positive for exposure, and #250 had titers unusually elevated which may represent recent infection.
Bluetongue (BT) – An antibody response was shown on three of the animals, while the other three, including #250, tested negative.
Brucella ovis (BO) – All tested negative.
Chlamydia – Although all showed some lower exposure, none had titers > 1 : 64 which would have indicated problems.
Mycoplasma spp. - The throat culture swabs taken had all animals testing negative.

The interpretation of these results show the animals to be mostly disease free, with the exception of PI-3. Of particular interest is the fact that animal #250 had elevated PI-3 titer levels, indicating recent infection, and #250 died less than three months after being captured. PI-3 has been problematic in this, and many other, sheep populations in the past, eventually leading to pasteurellosis, pneumonia and an all-age die-off of many animals.

Discussion

This project was needed to test the feasibility of using sophisticated GPS technology to provide essential data on bighorn sheep. To make that assessment, both GPS signal acquisition and multipath errors needed to be evaluated. A GPS satellite signal must first be received in order to record location data. For that data to be accurate, it cannot be distorted by bouncing off cliff walls or uneven terrain.

Unfortunately, the GPS-enabled ("satellite") collars purchased from the HABIT Research company promised much but delivered little. Complicating matters further, the HABIT Research company discontinued any dealings with wildlife telemetry shortly after this project began, and shortly afterward were purchased by a company dealing only in human telemetry. As such, very little technical support was received from the company, and the new company would not stand behind any faulty products from the past.

The HABIT Research satellite collars used for this research project have also completely failed in at least one other recent wildlife study. In a bison grazing study in Colorado, all four HABIT Research satellite collars used failed to collect any data for the year of use, and the problem was suspected to be in the preset internal clock. Not only did the HST feature fail to function, no data was stored on board in the memory of the satellite collars, and so even after the collars were removed from the bison, there was no data to retrieve manually. The report states, "The GPS collars from HABIT Research did not perform, and no GPS data was collected the first year of the study." (Shoenecker, K. A., et al. 2006. 2005 annual progress report: elk and bison grazing ecology: USGS Ft. Collins Science Center Open - File Report 2006 – 1267. pp. 10 and 37).

In concept, this sophisticated GPS equipment would immensely facilitate the acquisition of GPS data from animals in remote areas. However, in practical usage, it appears these poorly designed and inferior GPS radio collars, coupled with limited manufacturer technical support, could not surmount the inherent difficulties encountered in the rugged, closed-in areas of the park inhabited by bighorn sheep.

These inherent difficulties, manifested in the form of limited or no data, poor signal acquisition and multipath errors experienced with these HABIT GPS collars, have not been detected to this extent in other GPS collars that the author has used. Telonics, Inc. has a traditional generation 3 GPS collar that I have used for several years. These products have been successful in approximately 95% of my experiences with them in locational data, and the collars themselves have a failure rate of less than 10% of the 27 deployed the past six years. The disadvantages of these traditional Telonics GPS collars are a short battery life, the necessity to retrieve the collars from the field (after a timed-release causes the collars to drop off) to download the data because of no HST capability, and the fact that the locational data is old by the time of the download.

Conclusion

Based on our extensive use and testing of the telemetry equipment, I concluded that the weakness in the system was in the HABIT GPS collars. It seemed, with the paucity of data received from the collars, that the GPS collars were not collecting data on a regular or frequent schedule; indeed, some were not collecting any data at all and only had test data on them. After sending downloaded data to the HABIT Research company and discussing the issue with their engineer on numerous occasions, the conclusion was reached that the problem was in the GPS collar, with the timing or internal clock, having been preset at manufacture, possibly being the cause of malfunction of the HST feature.

Research question number one, whether a signal acquisition was possible in the rugged terrain, most likely proved to be a major factor in the lack of data collected on the GPS collars. The animals that were collared inhabited steep-walled, closed–in terrain, where it may have been impossible for the required minimum three satellites to be overhead at the required time. Even on aerial overflights, direct signals were difficult to obtain unless the fixed-wing aircraft was immediately over the animal's location. The data, or lack of it, leads to the conclusion that signal acquisition with these "state of the art" collars was greatly impaired by the rugged, walled–in terrain. Obviously, if no GPS satellite signal was received, no location information was recorded.

The second research question was determining the extent of multipath errors in this rugged, vertical environment. GPS signals bouncing off cliff walls can distort the timing of the signals creating erroneous location information. As noted above in the results, GPS collar #098 had less than 10% of its recorded locational data in the right place, and slightly less than 20% of collar #250's locations were accurate. Based upon this data from both collars, the conclusion can be drawn that the effect of multipath errors upon the proper location is extreme with these particular collars. However, on the positive side, approximately 23 and 53 locations, respectively, in three months were in the right location, giving more locations than either overflights or ground work would yield with traditional collars.

Despite the failure of the GPS collars and the touted high speed data transmissions, numerous positives have come from this project. The GPS data that was manually downloaded, valuable information needed in determining the feasibility of using this technology, did convincingly demonstrate the lack of GPS signal acquisition and an abundance of multipath errors, demonstrating the infeasibility of using this particular technology in the Maze District.

A greater understanding of the habitat and areas utilized by the Maze District sheep has been acquired. Overflights have shown movements and ranges of the animals. Ground observations have also shown this, as well as allowing the visual observation of the animals to determine demographics, lamb survival, habitat utilization and health.

If others of the GPS collars, when retrieved, have this percentage of correct GPS locations, much useful locational data will have been gleaned. It is anticipated, if the HABIT company is still believable, that these collars will continue to function for two or three more years, and additional direct, and limited GPS, data will be acquired and be of much value.

Based upon the negative answers to the research questions from these sophisticated GPS collars, efforts have already been, and will be made in the future, to educate other users to the failures and limitations of sophisticated GPS technology.

If the "state-of-the-art" GPS technology had worked as promised, a major step would have been made in eliminating the disadvantages and facilitating the tracking of wildlife in remote and rugged areas. However, GPS tracking technology is still not reliable, and the newer the technology, the less functional it currently seems. The more simple the GPS method, such as the basic Telonics model, the more reliable the signal acquisition and locational accuracy. When it comes to the still developing and error-prone technology of GPS tracking of wildlife in dissected terrain, it appears simpler is still better.

Future Research Needs

Due to the extreme importance of the region's bighorn sheep population, ongoing monitoring and research is important to ensure the survival of this fragile species. Demographics, lamb survival, critical lambing and rutting areas, habitat utilization, lamb survival and herd recruitment, and overall herd health and related disease issues are a few of the important research and monitoring needs which will continue to need to be addressed on a continuing basis.

In the remote and dissected habitat utilized by bighorn sheep, monitoring efforts maximizing the effectiveness of traditional VHF collars, and secondarily, simpler but reliable GPS technology, will be necessary. With numerous herds located in the southeast Utah metapopulation, cyclic monitoring of the herds will need to continue.

As this project showed, reliable results are not yet to be expected from sophisticated GPS collars and receivers. The development of new GPS systems to monitor wildlife on a reliable basis has been slow, and new systems have been error-prone. New systems, when possible, should be used in the future when research proves them to be consistently reliable. Future research and monitoring, however, should rely upon time-tested methods until research such as this project produces positive results from GPS systems.

Acknowledgements

The author wishes to thank the Canyonlands Natural History Association for the Discovery Pool Grant that made this project possible. Through their generous grant,

much valuable information was gained about the limitations of this specific GPS technology. In addition, much new and valuable data was collected on the demography of a remote population of sheep in the park.

Vicki Webster, SEUG Museum Curator, reviewed and edited the report, and the author wishes to thank her for her contributions, help and advice.

Personnel

Principal Investigator- Bill Sloan- NPS Wildlife Technician
Bill Sloan, NPS Wildlife Technician for the Southeast Utah Group, has been studying bighorn sheep for 27 years, 24 of which have been primarily in southeast Utah and northern Arizona. He is widely recognized as a regional authority on issues concerning bighorn sheep. He is well versed in the use of radio telemetry equipment and has much experience with GPS equipment. In 1990 Bill began a series of intensive foot surveys of the desert bighorn in Southeast Utah Group Parks to determine population status, habitat utilization and demographics of the local sheep populations. These early studies have been greatly enhanced by use of radio telemetry and other emerging technology. His monitoring continues to this day and has grown to include animals of the southeast Utah metapopulation on BLM lands. Bill has also studied the sheep populations, conducted sheep habitat assessment work and compiled herd histories in numerous parks throughout the Intermountain Region.

Gery Wakefield- NPS GIS Specialist
Gerald Wakefield has been a Geographic Information Systems (GIS) professional for ten years. He received an M.S. in Geography from the University of Arizona in 1995. He has been involved with GIS and Remote Sensing ever since then. He worked for three years with the U.S. Army Corps of Engineers, stationed at Fort Belvoir, Virginia. While there, he provided support for an environmental research and development team, specializing in the analysis of remotely sensed data. The data were used to aid in the development of rapid feature extraction, and military base ecosystem health. He is currently working for the National Park Service in Moab, Utah, as a GIS coordinator. While with the park service he has assisted in resource monitoring and management, including the maintenance of a bighorn sheep habitat and lambing model, and sheep location database. He has created graphic displays of sheep habitat and locational information. He also maintains an extensive database of GPS collected locations for several different disciplines, including cultural, facilities, law enforcement and environmental data.

The participants in this project outside the National Park Service included a contracted capture team, State Division of Wildlife Resources biologists, and BLM managers.

GPS Collar Locations -- 2008