Wildlife Society Bulletin 35(4):489–493; 2011; DOI: 10.1002/wsb.77

Tools and Technology

An Automatic VHF Transmitter Monitoring System for Wildlife Research

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ABSTRACT We describe an automated system for monitoring multiple very high frequency (VHF) transmitters, which are commonly employed in wildlife studies. The system consists of a microprocessor-controlled radio-frequency monitor equipped with advanced signal-processing capabilities that communicates with, and relays information to, a user interface unit at a different location. The system was designed for a capture-and-release snow leopard (*Panthera uncia*) study in Mongolia, where checking trap-site transmitters manually entailed climbing a hill with telemetry equipment several times each day and night. Here, it monitors the trap-site transmitters and actively produces an alarm when any of the traps have been triggered, or if the system has lost contact with any trap-transmitter. The automated system allowed us to constantly monitor transmitters from a research camp, and alerted us each time a trap was triggered. The system has been field-tested for 83 days from mid-September 2010 to mid-December 2010 in the Tost mountain range on the edge of Mongolia's Gobi desert. During this time, the system performed reliably, responding correctly to 45 manually generated alarms and 9 animal captures. The system considerably shortens the time the captured animals spend in traps, and also mitigates the need for manual trap-site transmitter monitoring, greatly reducing risk to the animal and the human effort involved. © 2011 The Wildlife Society.

KEY WORDS automatic system, monitoring, pulse detection, trap-site transmitter, VHF transmitter monitoring.

Studies of free-ranging wildlife often require that animals are captured, sedated, and fitted with tracking devices. Trapping is often the most effective method to capture species that occur in low densities (Goodrich et al. 2001), but even with suitable traps and trained personnel there is a risk that an animal will injure itself or even die in the trap. The risk often increases with the time that the animal is left in the trap (Onderka et al. 1990, Logan et al. 1999, Earle et al. 2003, Iossa et al. 2007). In situations where the animal needs to be chemically immobilized, the risk for complications related to factors such as stress, hypothermia, hyperthermia, and dehydration increases with the time the captured animal spends in the trap prior to immobilization (Fowler 1995, Ryser et al. 2005).

To decrease the risk to trapped animals, traps can be equipped with transmitters that alert the researchers when an animal has been caught. Global System for Mobile Communications (GSM) trap alarms that instantly report a capture via a cellular network were described by O'Néill et al. (2007) and Larkin et al. (2003). However, in areas lacking GSM coverage, radiotransmitters are typically used to monitor traps (see e.g., Benevides et al. 2008). This typically entails monitoring the radio transmissions at regular intervals using a very high frequency (VHF) receiver. In many cases researchers must climb to vantage points to acquire transmitter signals, which limits the frequency of trap checks, poses a potential risk to the researcher, and involves considerable human effort. Moreover, trap monitoring can be time-consuming and represent inefficient use of time, particularly when working with nocturnal animals, which necessitates trap monitoring throughout the night.

We have developed an automatic VHF transmitter monitoring system, called the Irbis System (irbis being Mongolian for snow leopard [*Panthera uncia*]). It was designed for trap-site transmitter monitoring, aiming to reduce the time that a captured animal spends in a trap and to curtail human effort involved in monitoring trap-site transmitters. It provides automatic monitoring of trap-site transmitters and emits a loud alarm in the event that a trap is triggered or the signal from the transmitter is lost. To the best of our knowledge, the Irbis System is the first system that can monitor trap radio transmissions with alarm functionality, and that can relay alarms from one place to another immediately. Examples of other telemetry monitoring systems include the Telonics TR-5 telemetry receiver (Telonics Inc., Mesa, AZ), which can detect and log telemetry pulses but lacks the alarm and relay functionalities of the Irbis System.

Received: 17 March 2011; Accepted: 30 August 2011;
Published: 8 November 2011

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The Wildlife Materials TRX-1000 (Wildlife Materials, Murphysboro, IL) detects telemetry pulses and can cycle through a large number of frequencies, but has no store, alarm, or relay functionality. Advanced Telemetry Systems receiver products (Isanti, MN) can detect and log telemetry transmissions and relay the logs to a remote site, but lack the alarm functionality and the self-check functionality of the Irbis System.

With minor modifications the Irbis System could also be useful in applications other than trap-site monitoring. The microprocessor that controls the operation of the system also performs the signal processing. It can be programmed with a signal analysis routine and rules of operation tailored to a given application (e.g., monitoring of other pulse-emitting VHF transmitters or other nonpulsed VHF signals). Generally speaking, the system is an intelligent, programmable VHF radio transmission monitor that can relay information extracted from the radio signals to a remote site.

Field tests of the Irbis System started in September 2010 as a part of a long-term study of snow leopard ecology being undertaken by Panthera and the Snow Leopard Trust in the Tost mountain range of South Gobi, Mongolia (see McCarthy et al. (2010) for a more detailed description about the research program).

STUDY AREA

The study area was located in the Tost-Tosonbumba Mountains, 250 km west of the provincial capital of Dalanzadgad. The area supported a high density of snow leopards and a diverse range of other large mammals, including Siberian ibex (*Capra sibirica*) and argali (*Ovis ammon*), grey wolf (*Canis lupus*), lynx (*Lynx lynx*), red fox (*Vulpes vulpes*), and Corsac fox (*V. corsac*). Approximately 230 herder families lived in the study area, with livestock holdings of nearly 40,000 animals, comprised of goats, sheep, camels, and horses. Annual precipitation was <130 mm/yr and temperatures ranged from −35° C to 38° C.

MATERIALS AND METHODS

The system is designed for use with Telonics TBT-500/600 trap-site transmitters. When armed, a TBT continually transmits short VHF pulses at an interval of 1.5 s, allowing the researcher to confirm that the trap is not triggered. In the event of a capture, a plunger gets pulled out of the transmitter, altering the VHF pulse transmission interval to 0.8 s. There are different versions and options for the TBT. The life of a TBT-500 with the standard setting for radio output power is 47.6 months.

The Irbis System detects the VHF pulses transmitted by a TBT and constantly monitors the pulse interval. It can easily be adapted to operate with other transmitters that transmit regular VHF pulses. The system operates on the assumption that there is at least one location from where all simultaneously deployed trap transmitter signals can be detected and are of sufficient amplitude for the system to detect their pulse rate. In mountainous areas, VHF transmissions are typically easier to detect from a high location, which is often far from research camp sites. The Irbis System consists of 2 separate stations, one for placement at a location where trap transmissions can be detected and one that should be placed in the living quarters. The stations, henceforth called "listening station" and "camp station," communicate via a one-way wireless link. See Figure 1 for a schematic overview of the Irbis System and its components.

The Irbis System is equipped with self-check functionality; the listening station sends a status signal to the camp station at regular intervals (typically 60 s). Should the camp station fail to receive this signal (e.g., because the transmission conditions have deteriorated or the listening station has

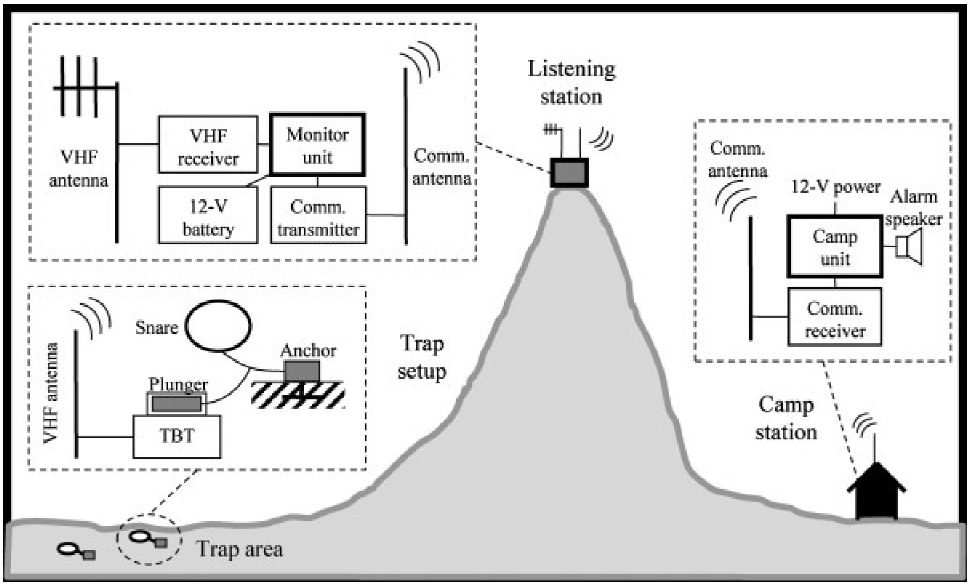

Figure 1. Overview of the Irbis System, field-tested from mid-September 2010 to mid-December 2010 as a part of a long-term study of snow leopard ecology in the Tost mountain range of South Gobi, Mongolia.

run out of battery or suffered a technical fault), the researcher is alerted by a light-emitting diode (LED) and an audible signal. Thus, when the camp station is silent, the system is assumed to be operational.

The Irbis System has been designed for long-term use in demanding field environments. The two stations and all their internal units are housed in rugged plastic cases with an IP67 dust and moisture proof rating (International Electrotechnical Commission 1999). Contacts, conduits, buttons, LEDs, and switches are rated to IP65 or better and selected for their ruggedness.

The listening station consists of a custom-designed monitor unit (see Fig. 2a), a telemetry receiver, a 12-V battery, and a wireless transmitter for communication with the camp station. At 20° C, the current consumption is approximately 250 mA. Therefore, a 32-Ah motorcycle battery is sufficient to power the listening station for 128 hr. This figure is reduced in cold conditions. The exact reduction depends on the low temperature properties of the battery. Typically, lead acid batteries lose 25–50% of their capacity when the temperature drops from 20° C to −30° C. A higher capacity battery and/or solar panels can be used if a longer battery life is desired. The core of the listening station is the custom-designed monitor unit, which accepts an audio signal from a commercial telemetry receiver connected to a VHF antenna mounted on a mast. The antenna should be horizontally omni-directional but reject signals from below and above. The wireless link transmitter is mounted on the antenna mast. During operation, the telemetry receiver cycles through preprogrammed transmitter frequencies, lingering for 8–30 s on each frequency. The monitor unit continuously analyzes the trap transmissions and their pulse rates. When the pulses correspond to normal trap operation (armed but untriggered trap), the system remains in a passive state; however, if the monitor unit detects a pulse rate corresponding to a triggered trap, it activates the "trap alarm" LED. If the monitor unit cannot detect any pulses for a specific TBT, it instead activates a "trap signal lost" LED. These events are instantly communicated to the camp station via the wireless link. At the camp station, the alarm activates within minutes of the trap event. The exact delay depends on the number of monitored transmitters and how often the receiver switches between different frequencies; an upper limit is given by the product of these factors plus a processing latency of no >10 s.

The "trap signal lost" alarm indicates that a trap-site transmitter cannot be heard and is no longer fulfilling its function. It is critical for the researcher to be made aware of this. It is possible that an animal that is caught in a trap dislodges the transmitter and/or its antenna in such a way that its transmissions become inaudible at the listening station. Therefore, the loss of a trap signal may, in fact, indicate a capture.

The camp station consists of a custom-designed camp unit (see Fig. 2b), a wireless receiver for communication with the listening station, and a speaker. It is powered by 12-V direct current (DC) power source and consumes approximately 100 mA. When the camp station receives a trap alarm or a trap signal lost event from the listening station, an LED corresponding to the type of alarm is lit on the camp unit and the speaker is activated. Using a directional antenna, researchers then determine which of the traps has been triggered or rendered inaudible. This may entail moving to a higher vantage point where signals can be acquired.

The Irbis System is equipped with alarm latch functionality. This means that the camp station speaker will be activated when an alarm is received and will continue to sound until the alarm is acknowledged. This minimizes the risk of overlooking an alarm event.

If researchers need to be away from camp, the camp station is mobile and can be moved so long as the wireless link between it and the listening station is maintained and a 12-V power source (such as a vehicle cigarette lighter) is available.

Field tests of the Irbis System were conducted from mid-September 2010 to mid-December 2010. We used modified Aldrich-style foot-snares set to capture snow leopards in the central range of our study area. During the field test, an Adeunis ARF 30 wireless receiver and transmitter pair (Adeunis RF, Crolles, France) was used to set up the communication link between listening station and camp station. Further, a Communications Specialists R-1000 telemetry receiver (Communications Specialists, Orange, CA) was used with a Followit Y-3 antenna and a Followit lightweight, telescopic, 7-m (22-ft) mast (Followit AB, Lindesberg, Sweden). Figure 3 shows a photo of the Listening Station, complete with mast and antenna.

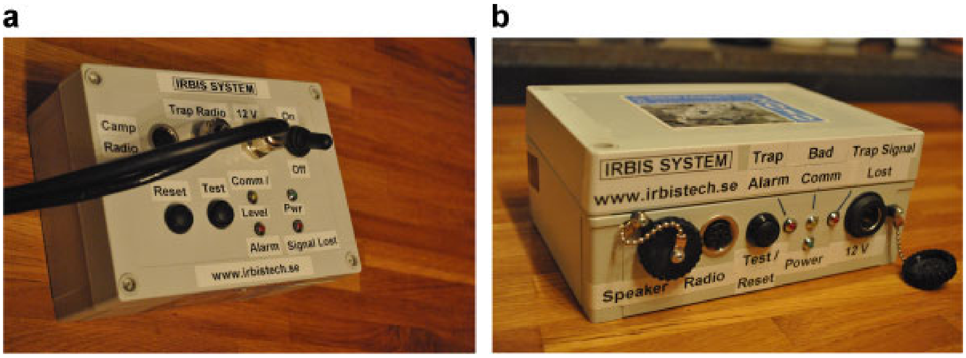

Figure 2. Key components of the Irbis System: (a) monitor unit and (b) camp unit. These electronic units are custom designed for the Irbis System, operate from 12-V DC power supply, and are moisture- and dustproof.

Figure 3. Photo of the listening station with mast and antenna (Gobi desert, Mongolia, autumn 2010).

RESULTS

During the first 4 weeks of the field test we simultaneously conducted manual trap-monitoring to ensure that the system performed as designed. We also generated 15 trap alarms by pulling the plunger from a transmitter, we simulated 15 transmitter failures by turning off a transmitter, and we generated 15 system malfunctions by disconnecting the listening station from the 12-V battery. The Irbis System successfully passed these initial tests, and then replaced manual trap monitoring from 10 October to 9 December, 2010. During this time, outside temperatures ranged from 20° C to −22° C.

We tested the system in 2 different trapping areas. In the first area, the system was active for 45 days and monitored 16 traps at distances from 404 m to 2,230 m. The system was active for 38 days, monitoring 11 traps, in the second area. Here, the distances were between 150 m and 1,790 m. The distance between camp and listening station was 214 m in the first area and 206 m in the second area. The battery in the listening station lasted 5 days early in the test period. This decreased to 4 days in December as a consequence of the temperature drop.

The system was active for 1,154 trap-nights, during which it alerted for 8 "trap alarms" and 1 "trap signal lost." No captures or triggered traps went undetected. The single "trap signal lost" alarm occurred when a snow leopard had been caught and knocked down the trap-site transmitter antenna. The response time from capture to arrival at trap site ranged from 20 min to 65 min, depending on how accessible the trap was. The captured animals were: 5 snow leopards, 2 dogs (*Canis lupus familiaris*), 1 ibex, and 1 domestic goat (*Capra aegagrus hircus*). All 5 snow leopards were caught during night, whereas the ibex and domestic animals were caught during daytime.

Approximately 25 false alarms were generated in the first month. Most of them were due to large temperature changes between day and night. This caused the transmitter frequencies to change, rendering the system unable to pick up the signals. By insulating the transmitters with pieces of foam mattress and burying them approximately 5 cm into the ground, the number of false alarms decreased to 8 the next month. These remaining false alarms were due to other transmissions near TBT frequencies.

In late November, nighttime temperatures dropped below −15° C, causing the receiver to drift in frequency and lose contact with the trap-site transmitters, which generated "trap signal lost" alarms. We solved this by installing a 12-V light bulb connected to a thermostat programmed to turn the lamp on when the temperature inside the box that houses the listening station dropped below 5° C. Although this worked, it is not an ideal solution because the power consumption increased significantly. In order to mitigate issues caused by frequency drift due to temperature changes, we are currently working on integrating the VHF receiver into the Irbis System. This will permit the VHF frequency setting to be controlled electronically from the Irbis System's microprocessor. The system will then become able to adapt to frequency changes. It is also hoped that the power consumption will be reduced.

DISCUSSION

Our work has demonstrated that it is possible to perform automatic monitoring of telemetry transmissions. The Irbis System proved reliable and successfully alerted for all capture events during the 83 days it was in use. Our study area is located in a high-altitude desert where the system was exposed to a harsh climate with dust storms, strong sunlight, and temperatures ranging from 20° C to −22° C. The strong sunlight created very large temperature shifts between day and night, which caused the VHF transmitters to drift in frequency, in extreme circumstances rendering the system unable to pick up the signals from the trap-site transmitters. In sheltered sites (e.g., forested areas) temperature shifts should be less problematic; however, the result of the current work to integrate the radios into the Irbis System should mitigate the problems associated with frequency drift.

We caught 5 snow leopards and 4 nontarget animals in the 83-day test period. Capture times reflect the period when the species are known to be most active (i.e., we caught most of the snow leopards during the night). The Irbis System is primarily designed to shorten the time an animal spends in the trap. If the target species is mainly nocturnal and the researchers do not process animals during night, there will be little benefit of using the system.

Despite the excellent results of the field test, the Irbis System cannot substitute for a country's or state's required trap checks. In countries with no legislated trap-interval checks, we would advise users to check the trap-site transmitters with a handheld antenna and receiver at least once per day as a safety measure. We also stress the need to visit the traps at least every other day to make sure that they have not been disturbed.

It is difficult to give an operational range for the system because VHF telemetry is highly affected by topography and climate, but we estimate that under most conditions the maximum distance (i.e., radio line of sight) between a trap and the listening station when using Telonics TBT-500 trap-site transmitters with TA-9 extension antennas and standard radio output power is about 4 km. However, efforts are currently being undertaken to improve the system's ability to detect weak transmissions. We expect that this will lead to a significantly increased detection range.

Prior to employing the Irbis System, we used to climb to an elevated position and manually checked the trap-site transmitters with a handheld antenna and receiver every third hour from early evening to late morning. The average time that a snow leopard spent in a trap with this monitoring scheme can be estimated to be about 2 hr (half the listening interval plus time to get to the trap). However, the maximum time is about 4 hr. With the Irbis System, the average time to reach a triggered trap came down to 40 min and the maximum time an animal may spend in the trap has been reduced to about 1 hr.

MANAGEMENT IMPLICATIONS

Our current design for an automated trap-site transmitter monitoring system can be used by projects that trap animals in areas of up to 4-km radius. This maximum range applies to radio line-of-sight conditions. The system monitors the trap-site transmitters constantly and alerts of a capture within minutes, considerably reducing the time that the animal spends in the trap. A trap design suitable for the target species in combination with trained personnel and the Irbis System should decrease the risk of injuries for the animals to a minimum, and keep risk and energy expenditure for the capture team low.

ACKNOWLEDGMENTS

We would like to express our gratitude to R. Sengupta, Snow Leopard Trust, Panthera, and Followit for their financial support. We would also like to acknowledge the technical support offered by Communications Specialists. G. Samelius, B. Söderström, H. Andrén, and C. Mishra gave valuable comments on the manuscript.

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Associate Editor: Breck.