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Auxiliary VHF Transmitter to Aid Recovery of Solar Argos/GPS PTTs

Christopher P. Hansen, Mark A. Rumble, R. Scott Gamo, and Joshua J. Millspaugh

Abstract

Abstract—*While conducting greater sage-grouse (*Centrocercus urophasianus*) research, we found that solar-powered global positioning systems platform transmitter terminals (GPS PTTs) can be lost if the solar panel does not receive adequate sunlight. Thus, we developed 5-g (mortality sensor included; Prototype A) and 9.8-g (no mortality sensor; Prototype B) auxiliary very high frequency transmitters that attach to the underside of GPS PTTs and work independently of the solar panel to aid in recovery of the units. Prototype A did not function properly because of an over-sensitive mortality sensor. Prototype B performed better; each was active upon recovery. Auxiliary transmitters were useful, but we encourage testing before deployment.*

Keywords: *auxiliary VHF transmitter, greater sage-grouse, radiotelemetry, solar Argos/GPS PTT*

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INTRODUCTION

Since 1959, very high frequency (VHF) radiotelemetry has aided extensively in studies of animal movements and demography (Le Munyan and others 1959, Kenward 2001b). Adaptation of global positioning systems (GPS) for attachment to animals substantially changed radio-tracking in wildlife research (Seegar and others 1996). More recently, GPS transmitters have been linked to solar-powered Argos Platform Transmitter Terminals (solar Argos/GPS PTTs), which enables them to transmit data via the Argos system. These units may be programmed to collect up to 1 location per hour and can transmit ultra-high frequency (UHF) signals at scheduled times so the study species may be tracked on the ground.

Initial costs upwards of $4,000 per unit and additional data transmission costs can be a hurdle for using solar Argos/GPS PTTs in animal studies. High initial costs often result in fewer marked animals and reduced statistical power (Hebblewhite and Haydon 2010). However, these high costs can be offset by reduced costs for acquiring data when compared to traditional VHF telemetry applications, particularly when study objectives require frequent and accurate location data in remote regions. Cost savings may be realized through fewer human resources, less mileage and logistical support, and less disturbance to animals (Hebblewhite and Haydon 2010), while increasing safety to researchers. Despite the potential benefits of solar Argos/GPS PTTs in animal studies, use of these units may not be cost effective if units are not recovered after animal mortality events. Transmitter recovery is important because of the expense to replace lost transmitters, as well as determining the fate of the study species and the reason for transmitter failure.

During the first year of a study on greater sage-grouse (*Centrocercus urophasianus*), we lost 7 solar Argos/GPS PTT units because they failed to obtain GPS fixes or transmit a UHF signal following an assumed animal mortality event. Consequently, we developed 2 auxiliary VHF transmitter designs that attach to the solar Argos/GPS PTT and work independently of the solar panel for power. In this paper, we provide a brief overview of the greater sage-grouse study that led to the development of the auxiliary VHF transmitters, a description of the transmitters and their attachment, and the overall performance of the transmitters in the field. We demonstrate how the addition of auxiliary VHF transmitters can aid in the recovery of solar Argos/GPS PTTs when the solar panel is obstructed and does not receive adequate sunlight to power the unit.

STUDY AREA

We conducted our study on the Overland Trail Ranch and surrounding areas between Rawlins, Wyoming and Saratoga, Wyoming. The Overland Trail Ranch comprises approximately 1,295 km^2 of checkerboard ownership. Approximately half of the land is private, owned and operated by The Overland Trail Cattle Company LLC, and approximately half is administered by the Bureau of Land Management (BLM), with a small portion owned by the State of Wyoming (figure 1).

The study area is considered desert and semiarid sagebrush-steppe, characterized by cold winters and hot summers (BLM 2012). Average temperatures range from -5.8 °C in January to 21.2 °C in July and average annual precipitation ranges from 16 to 36 cm, with increasing precipitation at higher elevations (Western Regional Climate Center 2009, BLM 2012). Elevations vary from approximately 1,890 m to 2,590 m above mean sea level.

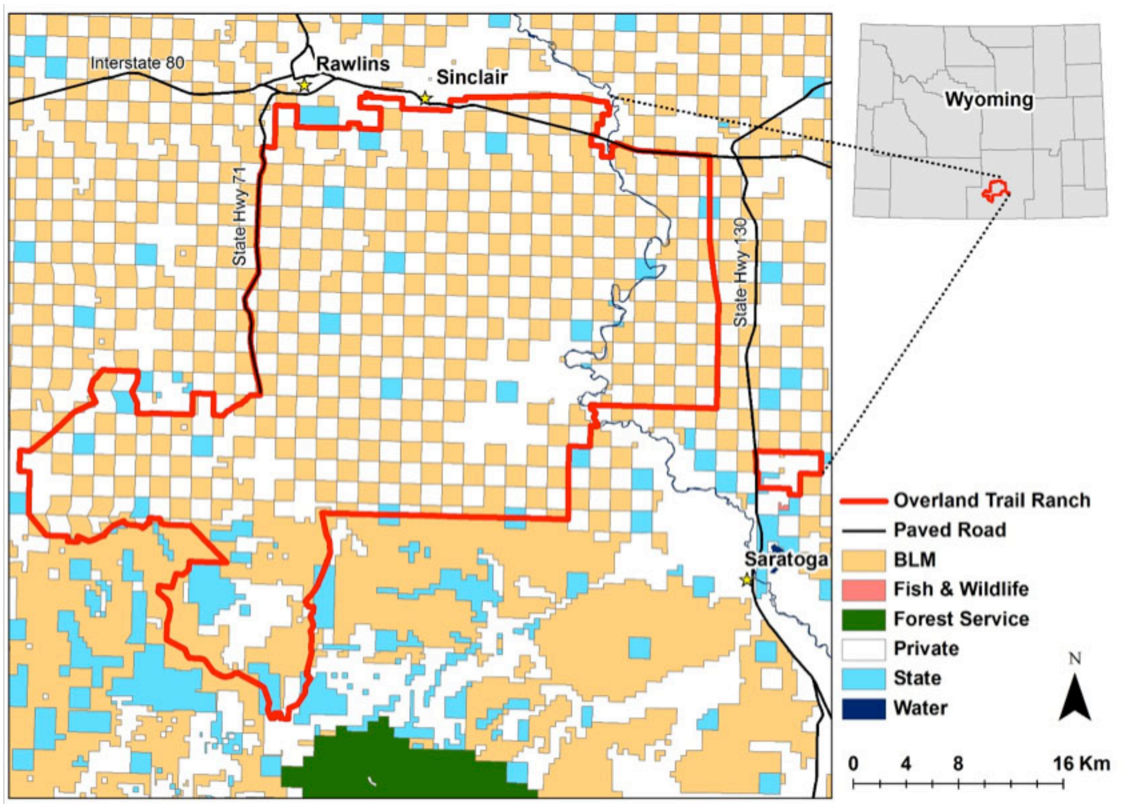

Figure 1. Map of the study area where we tagged greater sage-grouse with Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminals and auxiliary very high frequency transmitters from 2012-2014.

METHODS

Study Background

In April 2011, we began a study investigating the effects of wind energy development on male greater sage-grouse (hereafter referred to as sage-grouse). Our objectives required a detailed analysis of sage-grouse survival, movement, and resource use over a large study area with limited road access. Thus, we used 30-g Solar Argos/GPS PTT-100 units (hereafter referred to as GPS PTTs) with UHF ground track (accuracy ±18 m; Microwave Telemetry, Inc., Columbia, Maryland) on adult/yearling male sage-grouse. We programmed GPS PTTs to store five to nine locations every day for each sage-grouse and locations were transmitted to Argos satellites at 4- to 8-day intervals. The UHF ground track option on our GPS PTTs, which allowed us to track sage-grouse using an antenna and receiver, was active during spring and summer but disabled in winter to conserve battery life during periods of low light and short days.

Because GPS PTTs are dependent on solar energy for power, we tested how long it would take for power to be lost if the solar panel was not directly exposed to sunlight after a sage-grouse mortality event. We placed charged GPS PTTs outside, in multiple positions (upside down and sideways, facing each cardinal direction), and determined a fully charged GPS PTT lying upside down lost battery power in approximately 48 hours, while a GPS PTT lying on its side lost power in 5-8 days, depending on the direction the solar panel faced and the amount of vegetation surrounding the tag.

We captured sage-grouse using spotlighting and hoop-netting techniques (Giesen and others 1982) and attached GPS PTTs to the rumps of sage-grouse using the Rappole and Tipton (1991) method. The University of Missouri Institutional Animal Care and Use Committee approved the trapping and handling protocols

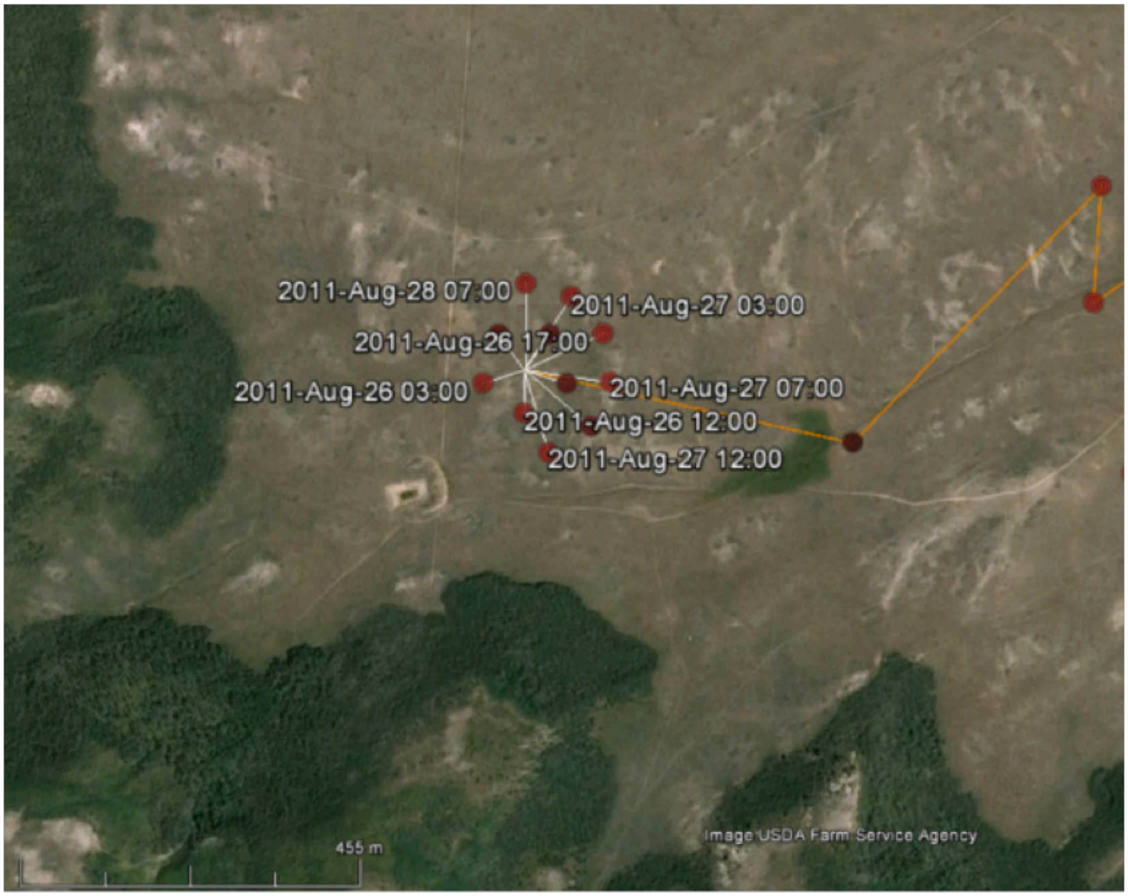

Figure 2. Example of a cluster of Global Positioning Systems locations (red circles), gathered from Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminals after a male greater sage-grouse mortality in Carbon County, Wyoming in 2011. Locations have been separated slightly to show all locations at one site.

(MU IACUC #6750). When a sage-grouse mortality event occurred, we typically witnessed a cluster of GPS locations at approximately the same site, downloaded from Argos satellites (figure 2). If the solar panel received adequate sunlight, we located the transmitter using the UHF signal and a 4-element yagi antenna. If the solar panel on the GPS PTT did not capture enough sunlight, the unit stopped transmitting UHF signals and several field technicians visually searched for the GPS PTT near the cluster of GPS locations.

In October 2011, 3 GPS PTTs stopped transmitting without evidence of a mortality event. We intensively searched the area surrounding the final transmitted location for each sage-grouse, but could not find the GPS PTTs or any evidence of mortality. Over the next year, 7 GPS PTTs stopped functioning and were not recovered.

Auxiliary VHF Transmitter Development

In 2012, we designed an auxiliary VHF transmitter (i.e., Prototype A; table 1) that could be attached to GPS PTTs using flexible silicone caulk (figure 3). The transmitter was manufactured by Advanced Telemetry Systems (ATS; Isanti, MN). With Prototype A attached, GPS PTTs weighed approximately 35 g, which is <2.5% of the body mass of yearling and <2% of the body mass of adult male sage-grouse across much of their range (Beck and Braun 1978). Prototype A included a mortality sensor designed to transmit a signal only if the transmitter was motionless for 24 hours.

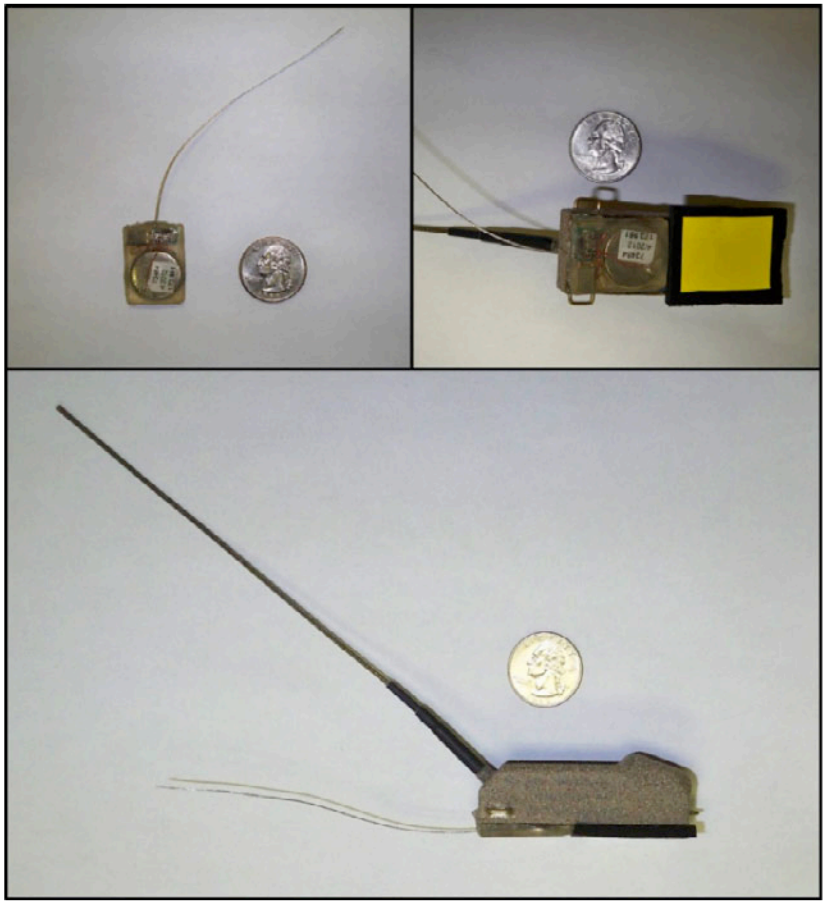

Figure 3. The 5-gram auxiliary very high frequency transmitter (Prototype A; top left) and its attachment to the underside of a Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminal, with bottom (top right) and side (bottom) views. Total weight of the unit was 35 grams. The black and yellow square is a neoprene pad with yellow tape to facilitate visual location of the transmitter if it was upside down. We recommend adding additional neoprene padding across the bottom of the transmitter to reduce bird discomfort.

In 2013, we designed a second auxiliary VHF transmitter (Prototype B; table 1) that transmitted a continuous signal. Continuous transmission from Prototype B enabled us to track a live sage-grouse during periods when the UHF signal was turned off. Prototype B included 2 batteries to extend the operational life of the unit and, as with Prototype A, was attached to the bottom of GPS PTTs with flexible silicone caulk (figure 4). The complete unit weighed approximately 40 g (<2.5% of a juvenile male mass and <2% of adult male mass).

We tested performance of GPS PTTs with Prototype A or B attached (test GPS PTTs) and GPS PTTs with no VHF transmitter attached (control GPS PTTs) for ≥2 days before deploying them on sage-grouse. If VHF transmitters affected performance of GPS PTTs, we expected to receive fewer locations or locations with inferior accuracy. After testing, we deployed transmitters on adult and yearling male sage-grouse.

Whenever we recorded a mortality event for a sage-grouse tagged with Prototype A, we waited at least 3 days before recovery to allow the VHF transmitter sufficient time to activate. We recovered Prototype B GPS PTTs as soon as possible after a mortality event. If a test GPS PTT stopped functioning, we conducted aerial and ground searches while listening for the auxiliary VHF signal. We conducted a known-fate survival analysis in Program MARK (White and Burnham 1999) and compared average daily cumulative movements among test and control GPS PTTs to assess whether the added weight of prototype transmitters affected male sage-grouse survival and movements.

Table 1—Specifications of two auxiliary very high frequency transmitters (Advanced Telemetry Systems Isanti, MN) affixed to 30-g Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminals and tested on male greater sage-grouse in Carbon County, Wyoming from 2012 – 2014.

Features	Prototype A	Prototype B
Model	A2720	A2720
Cost per unit	$165.00	$179.00
Pulse Rate	40 ppm	30 ppm
Pulse width	15 ms	15 ms
Mortality switch[a]	24 hr	-
Battery life while transmitting	90 days	723 days
Battery life while not transmitting[a]	1744 days	-
Weight	5.3 g	9.8 g
Length (without antenna)	29 mm	53 mm
Width	21 mm	21 mm
Height	3 mm	3 mm
Antenna length	102 mm	153 mm
Line of sight signal distance[b]	1.6 km	2.0 km

[a] Prototype B had no mortality switch and transmitted at all times.
[b] Signal distance will vary with topography and ground cover.

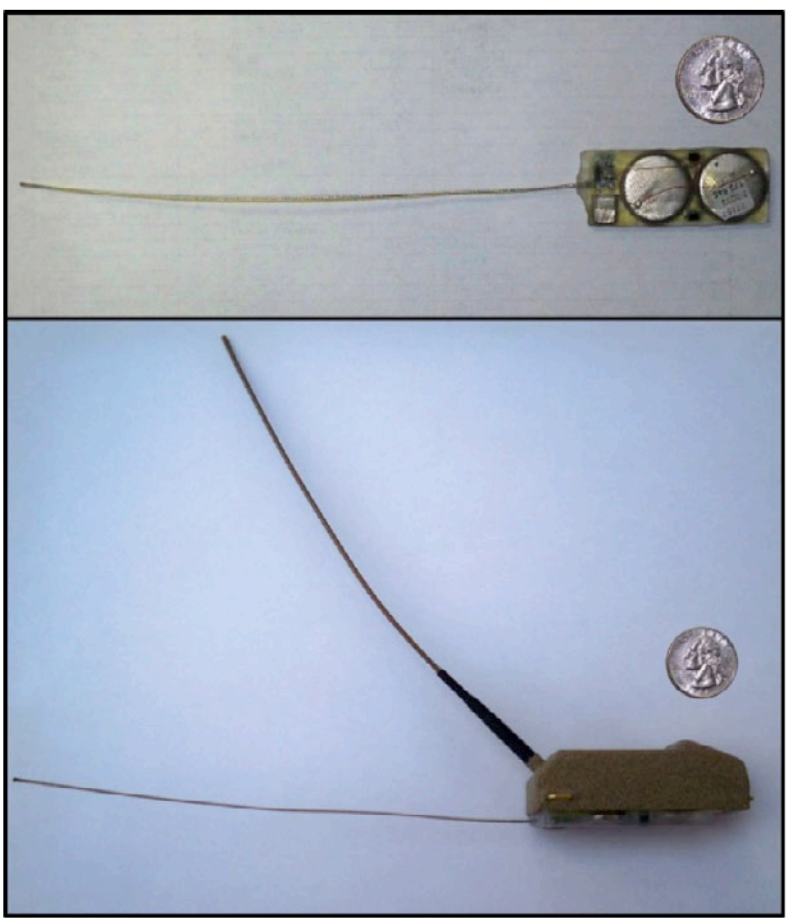

Figure 4. The 9.8-gram auxiliary very high frequency transmitter (Prototype B; top) and its attachment on the underside of a Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminal, with side view (bottom). Total weight of the unit was approximately 40 grams. Neoprene padding was removed to show transmitter detail. We recommend adding neoprene padding across the bottom of the transmitter to reduce bird discomfort.

RESULTS

We attached GPS PTTs with Prototype A to 30 male sage-grouse in 2012, GPS PTTs with Prototype B to 12 male sage-grouse in 2013, and GPS PTTs with no VHF transmitter to 47 male sage-grouse in 2012 and 2013. Test and control GPS PTTs met the manufacture accuracy specification of ±18 m (Protoype A: 16.33 m, SE = 2.16; Prototype B: 13.18 m, SE = 0.94; Control: 15.92 m, SE = 0.78). The average number of locations/day/sage-grouse collected among test and control GPS PTTs throughout the year was similar (table 2).

Table 2—Average number of locations/day/greater sage-grouse, standard errors (SE), and sample size (n) collected from Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminals with and without (Control) Prototype A or Prototype B very high frequency transmitters, attached in Carbon County, Wyoming from 2012-2014.

Season	Prototype A	SE	n	Prototype B	SE	n	Control	SE	n
Spring (March 1 – June 14)[a]	7.04	0.16	27	7.46	0.09	3	7.33	0.07	36
Summer (June 15 – Nov. 14)[a]	4.62	0.03	26	4.62	0.03	11	4.59	0.02	38
Winter (Nov. 15 – Feb. 28)[a]	4.23	0.23	17	4.36	0.12	11	4.34	0.15	29

[a] Maximum number of locations/day/sage-grouse collected in spring, summer, and winter were 8, 5, and 5, respectively.

Average daily cumulative movements (April – December) for male sage-grouse tagged with Prototype A (1,602 m; 95% CI: 1,487 m – 1,715 m) and Prototype B (1,774 m; 95% CI: 965 m – 2,582 m) was similar to sage-grouse tagged with control GPS PTTs (1,672 m; CI: 1,468 m – 1,875 m). Survival of male sage-grouse tagged with test and control GPS PTTs was also similar (table 3).

From April 2012 – January 2014, we recovered 52 GPS PTTs (24 with Prototype A, 3 with Prototype B, and 25 with no VHF transmitter) after sage-grouse mortality or attachment failure (the transmitter fell off before sage-grouse mortality). Thirty-one (~60%) of the retrieved GPS PTTs did not have UHF signal because they were upside down or under thick vegetation or snow. During this time period, 20 GPS PTTs (9 control and 11 with Prototype A attached) temporarily stopped providing GPS locations due to low battery power. Thirteen of these units began transmitting GPS locations again in spring and summer on live birds. We confirmed these 13 temporary transmitter failures were due to feathers covering the solar panel, combined with low light conditions and short days. Of the remaining 7 GPS PTTs, we recovered 1 after a sage-grouse mortality event using the VHF signal from Prototype A, 3 after they received enough sunlight to recharge the batteries and provide GPS locations at the mortality site, and 3 have not been recovered.

Table 3—Survival estimates, 95% confidence limits (L95% and U95%), and sample size (n) for male greater sage-grouse tagged with test (Prototype A or Prototype B auxiliary very high frequency transmitters attached) and control (no very high frequency transmitter attached) Microwave Telemetry, Inc. solar Argos/Global Positioning Systems Platform Transmitter Terminals in Carbon County, Wyoming from 2012 – 2014.

	April 1, 2012 – April 1, 2013				Sept. 1, 2013 – Jan. 15, 2014[a]			
Transmitter	n	Survival (%)	L95%	U95%	n	Survival (%)	L95%	U95%
Control	11	34.6	12.6	66.0	22	90.4	68.6	97.6
Prototype A	27	45.9	27.9	65.0	6	83.0	36.3	97.7
Prototype B[b]	-	-	-	-	11	89.3	51.3	98.5

[a] Prototype B sample sizes were too low (n = 3) to complete survival analyses before Sept. 1, 2013.
[b] Sage-grouse were not tagged with Prototype B until April, 2013.

Of the 24 Prototype A GPS PTTs we recovered, only 1 had an active VHF signal. We located the remaining 23 units either using the UHF signal or ground searches. The VHF signal was active on all 3 recovered GPS PTTs with Prototype B attached. In total, auxiliary VHF transmitters helped us locate 3 GPS PTTs (1 Prototype A, 2 Prototype B) that had lost power and stopped transmitting locations.

DISCUSSION

Addition of an auxiliary VHF transmitter to GPS PTTs did not affect performance of the transmitters. Radio transmissions can sometimes degrade the performance of GPS receivers and accuracy of locations (Ward 1996, Balaie and others 2006) and GPS transmitters can interrupt duty cycles in VHF transmitters (Roth, personal communication). Bedrosian and Craighead (unpublished report) found that interference from a 3-g VHF transmitter attached to GPS PTTs and deployed on sage-grouse in Wyoming might have caused 2 GPS PTT failures. However, they also experienced GPS PTT failure from one unit that did not have a VHF transmitter attached. After 2 years of testing, we did not observe a decrease in the number or accuracy of GPS fixes by adding auxiliary VHF transmitters to GPS PTTs. We do not believe the temporary interruption of locations from the 11 test GPS PTTs in our study resulted from VHF signal interference, given 9 control GPS PTTs also stopped transmitting for similar reasons. Although we did not detect a reduction in performance of the GPS PTT or VHF transmitter when attaching them together, it is important that units are tested for compatibility to avoid complications prior to deployment.

While our sample size was low, there was no evidence that adding 5-g or 9.8-g VHF transmitters to GPS PTTs had large effects on survival or movements of male sage-grouse. Similar to our findings, interseasonal movements of sage-grouse tagged with GPS PTTs were not different than movements of sage-grouse tagged with smaller VHF transmitters (Fedy and others 2012). However, increasing transmitter size/weight reduced survival in ring-necked pheasants (*Phasianus colchicus*) in Illinois (Warner and Etter 1983) and greater prairie-chickens (*Tympanuchus cupido*) in Missouri (Burger and others 1991). Burger and others (1991) reasoned that decreased survival of greater prairie-chickens may have resulted from the increased shiny surface area of larger transmitters, not the added weight. Our auxiliary VHF transmitter was placed underneath the GPS PTT; thus, it did not increase the exposed surface area of the unit. Warner and Etter (1983) found that ring-necked pheasant survival was most affected by transmitter weights >2% of body mass. Transmitter weight, with VHF transmitter attached, averaged 1.48% (SE: 0.30) of male sage-grouse body mass in our study. Further, Warner and Etter (1983) used backpack-mounted transmitters that affect behavior and demography of some avian species including ruffed grouse (*Bonasa umbellus*; Gullion and others 1962), waterfowl (Dwyer 1972), ring-necked pheasants (Marcström and others 1989), and spotted owls (*Strix occidentalis*; Foster and others 1992). In this study, we attached GPS PTTs to the rumps of sage-grouse (Rappole and Tipton 1991) because this technique has fewer effects on avian physiology (Suedkamp Wells and others 2003), behavior, and survival than a backpack mount (Bowman and Aborn 2001, Bedrosian and Craighead, unpublished report). While we did not specifically evaluate the effects of rump-mounted transmitters on sage-grouse, there is likely an upper transmitter weight threshold in which behavior is affected and that threshold is species specific. Researchers should consider total transmitter weight (Cochran 1980, Caccamise and Hedin 1985) and attachment methods (Kenward 2001a) before applying them to animals.

Prototype A failed to activate following 23 of 24 mortality/attachment failure events because the mortality sensor was too sensitive. Any slight movement of the VHF transmitter's antenna, often from wind, caused the unit to stay in "live" mode, resulting in a lack of signal transmission. Even if Prototype A activated after being motionless for 24 hours, it could deactivate with any further movement. A mortality switch could still have utility if the sensor was less sensitive and the VHF transmitter had a mortality lock so it continued emitting a signal after the mortality switch activated. Further, reducing the time it takes for the mortality switch to activate might be beneficial, but researchers must balance the time with life history of the animal (e.g., hens sitting on a nest remaining motionless). These are important characteristics to consider if a mortality switch on the auxiliary VHF transmitter is used.

Prototype B was designed to transmit continuously, which made it possible to recover all GPS PTTs with Prototype B attached and track live sage-grouse when the UHF was not active. GPS PTTs on many tagged male sage-grouse in our study lost power when feathers presumably covered the solar panel. Thus, having a continuous VHF signal, independent of the solar panel, might be useful to track and recapture sage grouse and reset the GPS PTT on top of feathers. Also, hen sage-grouse tagged with GPS PTTs can lose solar power while sitting on nests, under thick vegetation (Bedrosian and Craighead, unpublished report). Incorporating Prototype B with GPS PTTs on hens could facilitate monitoring the status of nests when GPS PTTs have lost battery power. As with Prototype A, modifications could be made to Prototype B to better suit the needs of the investigator. For example, batteries may be removed to reduce weight if additional battery life is not needed.

Most GPS PTTs can be recovered without the need of an auxiliary VHF transmitter. However, saving just 1 GPS PTT is equivalent to the cost of ~22 auxiliary VHF transmitters, so we feel the addition is warranted. The auxiliary VHF transmitters enabled us to find GPS PTTs in locations not receiving sunlight, in thick vegetation or under snow, and reduced our search effort. The ability to recover transmitters and determine sage-grouse fate led to more precise, unbiased estimates of survival. We only tested the auxiliary transmitters on sage-grouse, but they could be useful in studies using GPS PTTs on other species. Researchers incorporated a similar auxiliary transmitter design on osprey (*Pandion haliaetus*) and saved 3 GPS PTTs, using the auxiliary VHF transmitter signal, that otherwise might not have been recovered (Washburn, personal communication).

While these results demonstrate the utility of auxiliary VHF transmitters for locating inoperative GPS PTTs, we have discussed several caveats that should help other researchers apply this approach. Some manufacturers provide the option of adding a VHF transmitter to the GPS PTT, so we encourage researchers to investigate these options. If a VHF transmitter addition is not available through the manufacturer, the designs we discussed in this paper are viable options. Nonetheless, it is important to test the dual transmitter applications to ensure the quality or integrity of resulting data are not compromised.

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