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USE OF SATELLITE TRAP TRANSMITTERS IN CAPTURING MOUNTAIN LIONS

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USE OF SATELLITE TRAP TRANSMITTERS IN CAPTURING MOUNTAIN LIONS— The use of safe and humane methods for the capture of wild animals is imperative in wildlife research, wildlife damage management, and feral animal control. When capturing animals successfully and humanely, several items must be addressed, including animal safety, personnel safety, non-target captures, and cost (Sikes et al. 2016). Additionally, public pressures against the use of traps have led to significant changes in trapping regulations across North America and beyond (Andelt et al. 1999, Darrow and Shivik 2008) and can place research projects at risk to loss of Institutional Animal Care and Use Committee (IACUC) approval (Larkin et al. 2003). Various types of trap transmitters have been used to address these concerns. Reported within the literature are multiple homemade, modified, and commercially available trap transmitter systems using very high frequency (VHF) radio, cellular phone networks, or trail cameras with cellular communication as mediums (Nolan et al. 1984, Larkin et al. 2003, O'Neill et al. 2007, Johansson et al. 2011, Thompson and Prude 2015). More recently, several studies indicate using commercially available satellite trap transmitters (Heinemeyer and Squires 2012, Riley et al. 2014, Scrafford and Boyce 2014).

While generally reliable, every trap transmitter system has limitations, which should be addressed before being implemented in the field. However, literature on the effectiveness and reliability of satellite trap transmitters are lacking, making informed decisions more difficult for anyone considering their use. Therefore, we report on our experience using satellite trap transmitters to monitor foothold traps set to live-capture mountain lions (*Puma concolor*). Our goal was to provide a thorough evaluation of this trap transmitter system to aid others considering implementing satellite trap transmitters.

We used Vectronic TT3 satellite trap transmitters (Vectronic Aerospace GmbH, Berlin Germany) on the Iridium satellite system to monitor foothold traps set to live-capture mountain lions during the winters of 2014–2015 and 2015–2016. The study area was located in western North Dakota, primarily the Little Missouri Badlands Region (Badlands Region). The Badlands Region was characterized by a highly variable landscape of clay slopes, steep canyons, buttes, and bottomlands carved by the Little Missouri River (Hagen et al. 2005). North and east facing slopes typically contained stands of Rocky Mountain juniper (*Juniperus scopulorum*) and green ash (*Fraxinus pennsylvanica*) while riparian areas supported stands of cottonwood (*Populus deltoides*). Shortgrass prairie was dominant on southern and western slopes, plateaus, and bottomlands (Hagen et al. 2005).

Specifications of the TT3 trap transmitter and how it operates can be found at <http://www.vectronic-aerospace.com/wp-content/uploads/2016/04/Flyer_TT3-Trap-Transmitter.pdf>. Perhaps the most important consideration is that the unit must have a relatively clear view of the sky to ensure proper communication with satellites (Vectronic Aerospace GmbH). Furthermore, it is the responsibility of the user to secure the transmitter and trap, and this will vary depending upon the situation. In our case, we attached the transmitters to the base of a tree near the trap site. We created "L-shaped" brackets constructed of plywood and bolted the transmitter to the bracket, and then used a standard bungee cord to firmly mount the bracket and transmitter to the base of the tree (Fig. 1).

We used most of our traps and transmitters in conjunction with a baited "cubby set", commonly used to trap mountain lions, bobcats (*Lynx rufus*), bears (*Ursidae*) and other species (Nolan et al. 1984, Halstead et al. 1995, Wilckens 2014), while we used others on trails near active bait sites (Logan

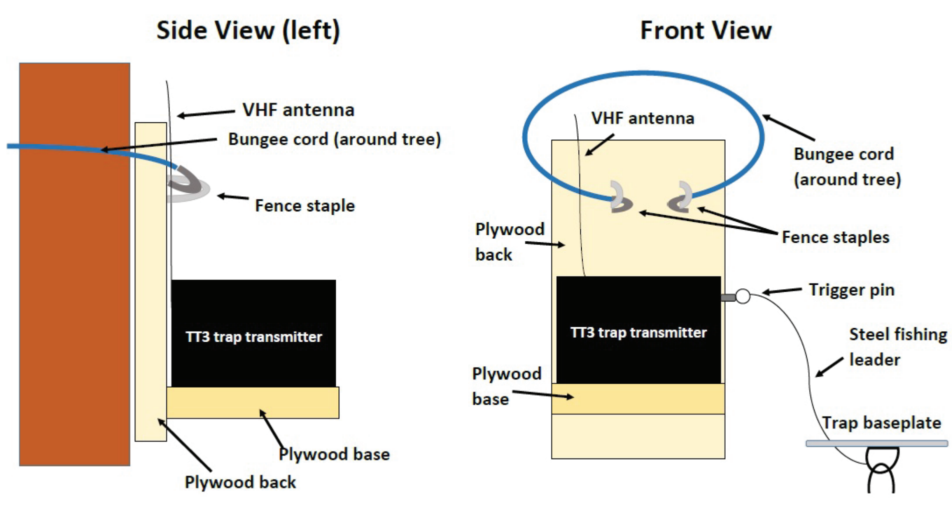

Figure 1. Illustration of homemade bracket and general setup of TT3 trap transmitter used to monitor a foothold trap set to capture mountain lions in the North Dakota Badlands from 2014–2016.

et al. 1999). We observed activity at all trap sites by installing trail cameras (Extreme HD 40, Covert Scouting Cameras, Inc., Lewisburg, Kentucky, USA). For both cubby and trail sets, we bedded a trap either in the cubby entrance or trail and secured it to a cable wrapped around the base of a tree ≤ 45.7 cm away. The trap transmitter was then attached to the same tree, using a bungee cord and our bracket (Fig. 2). To attach the transmitter pin to the trap, we used ~45.7 cm of steel fishing leader (Eagle Claw, Wright and McGill Company, Denver, Colorado, USA). The swivels on both ends allowed us to easily attach the leader to the wire ring on the transmitter pin, as well as loop and secure the leader around the base of the trap. Additionally, leaders were inexpensive, came in various lengths, were sufficiently strong, and rodents were not inclined to chew on the steel leader. We fastened the leader to the first chain link at the base of the trap and made sure not to use an excessive leader length. This ensured the pin would be pulled from the transmitter immediately if an

Figure 2. Example of the typical setup used to monitor foothold traps set to capture mountain lions in the North Dakota Badlands from 2014–2016. The TT3 and bracket was attached to the base of the trap tree with a bungee cord. The trap (inside the rectangle of guiding sticks) was attached to a cable wrapped tightly around the base of the tree. Finally, the trigger pin was attached to the trap chain with a steel fishing leader.

animal was caught, due to the trap being pulled up out of its bed; if the trap fired but the animal was not captured, the trap likely would not be pulled up from the bed and the transmitter would not activate. To avoid non-target captures of small mammals, we increased the trap pan tension so that it took a considerable amount of pressure to fire the trap. When we left traps and transmitters set for several days or weeks at a time, we physically checked our sets daily to verify the transmitter was still attached and working properly, and to satisfy our approved animal welfare protocol. Once a capture message was received, we mobilized and attended to the capture as quickly as possible. Animal handling methods used in this project followed guidelines approved by the American Society of Mammalogists (Sikes et al. 2016) and were approved by the Institutional Animal Care and Use Committee at South Dakota State University (Approval number 14-094A).

We captured four mountain lions (3 F, 1 M) during the winter of 2014–2015 and four mountain lions (2 F, 2 M) and one non-target raccoon (*Procyon lotor*) during the winter of 2015–2016 (Table 1). During the first winter, we had traps and transmitters deployed for a total of 191 trap nights. We relied more on our satellite trap transmitters during the second winter, using them for a total of 445 trap nights. By comparing a time-stamped trail camera photo of each capture to the time we received the initial capture notification text/email, we calculated an average capture notification time of 23.7 minutes (range = 3 to 104 min; Table 1).

We did not experience any false alarms or captures where the transmitter failed to send a message. During capture events, the trap transmitters received minor damage, including a few bite marks and/or scratches. Additionally, two transmitter brackets were broken and five transmitter pins were either lost or broken. However, the brackets were easy to fix or replace, and we were able to order a bag of replacement pins from the manufacturer.

The TT3 trap transmitter was programmed to send one daily status email to indicate to the user it was operating properly and the transmitter had not fired. We received a total of 510 individual daily status emails for a total of 636 trap nights during the study (80% daily success). While not uncommon to miss an individual daily email from a transmitter, it became a concern when we missed status emails from the same transmitter for two or three consecutive days. When this occurred, we conducted a test trigger during our daily trap checks to verify proper transmitter function. Of 57 test triggers conducted at actual trap sites, we received 46 initial capture messages within three minutes (81%), seven messages at the 30-minute mark (12%), and two messages at the 60-minute mark (4%). However, two test triggers failed to send a capture message. Furthermore, the VHF was not functioning on these two transmitters, indicating neither transmitter was working properly. Both transmitters were removed immediately and sent back to the manufacturer for refurbishment. Finally, we experienced one occasion with no emails received from any transmitter for two consecutive days. We inquired with the company and were told their server was experiencing problems. By the end of the day, the server situation was resolved and all communication resumed.

There are several advantages to using satellite trap transmitters over either traditional radio transmitters or no transmitter at all. One of the principal advantages is the immediate capture notification. We acknowledge that notification times may not be 'immediate'. However, most capture messages were received within 15 minutes of the capture, likely satisfactory for most applications. Prompt capture notifications lead to faster response times, thereby reducing the time the animal spends in the trap. Less time in the trap lowers the likelihood of the animal injuring itself or escaping, as well as exposure to the elements and other animals (O'Neill et al. 2007, Sikes et al. 2016). When chemical immobilization

Table 1. True time of capture, time we received the first transmitter message indicating the capture event, and time elapsed (min) for nine total capture events, North Dakota Badlands, 2014–2016.

Animal	Time of Capture	TT3 Notification Time	Time Elapsed (min)
F122	0701	0811	70
F123	0730	0738	8
F124	0445	0452	7
M125	2023	2036	13
M126	2324	0108	104
F127	2006	2009	3
F128	2329	2332	3
F123 (recapture)	0420	0422	2
Raccoon (nontarget)	0036	0040	4
Mean ± S.E.			23.7 ± 12.3 min

is needed, the risk of complications due to stress, hyper/hypothermia, and dehydration is positively correlated with the length of time the animal is restrained (Johansson et al. 2011). Finally, in situations where public disapproval of trapping may be an issue, immediate capture notification could be used to address and satisfy concerns of humane treatment of trapped animals, specifically by minimizing animal stress, pain, and likelihood of injury (Andelt et al. 1999, Larkin et al. 2003, Sikes et al. 2016).

Another important advantage is the ability to use this type of transmitter almost anywhere with a relatively clear view of the sky. Iridium satellite coverage is worldwide and dependable; on the other hand, Globalstar satellite communication is slightly more economical but is coverage dependent, meaning that some areas have weak or no signal depending on where you are on the globe (Vectronic Aerospace GmbH). Depending on your choice of satellite communication module, these trap transmitters are capable of being used almost anywhere and are not restricted to areas of good cellular phone service (as when using cellular trail cameras) or the need to be within radio transmission range of the transmitters.

Another possible advantage of satellite trap transmitters is the improved efficacy of running a trapline. Using a reliable system of satellite trap transmitters could lead to lower overall costs associated with checking traps by reducing the number of visits to the sites, lowering gas/vehicle costs, requiring fewer technicians, and less flight time. In addition, more traps may be monitored simultaneously, increasing total number of trap nights. This has the potential to increase the overall number of captures within a capture season. However, trap transmitters cannot replace physically checking traps, and we do not suggest running a trapline relying solely upon trap transmitters. Instead, using satellite trap transmitters in conjunction with regular physical checks (at intervals approved by IACUC committees) could lead to a more efficient and cost-effective trapline and improve animal welfare.

Despite the advantages offered by satellite trap transmitters, some drawbacks exist. Even though satellite trap transmitters should last for several years, depending upon frequency and duration of use, the cost may be prohibitive to many projects. The Vectronic TT3 units we used cost $798/unit when we purchased them in 2013, and we paid a fee of $2.66/unit/month. Thus, researchers need to be aware of the costs when budgeting. Additionally, because transmitters were expensive, we were concerned initially with damage to the units. This certainly remains a possibility if the animal has access to the transmitter, but in our study the transmitters held up well.

We experienced malfunctions of individual transmitters as well as a server failure during our study. Both transmitter units that stopped working had failed internally, and were not damaged from a capture, the unit being dropped, or weather. We were reassured by the manufacturer that transmitters are typically hardy units and failure is rare, but our results demonstrate that it remains a possibility. The unit and server failures resulted in approximately a dozen trap nights without trap monitoring, which we were unaware of at the time. Once refurbished, the units performed equally as well as new units. While equipment failures are likely impossible to prevent, the best course of action is to remain vigilant in testing transmitters, watching for status emails, and exercising caution by physically checking traps.

Even though satellite communication offers much flexibility, many wildlife captures take place in rugged and/or forested areas. This type of vegetative and topographic cover can hinder satellite communication, minimizing one of the principle advantages of satellite trap transmitters. Our captures all occurred in stands of either Rocky Mountain juniper or green ash, surrounded by topography ranging from relatively flat to steep hillsides. We did not take formal measurements of canopy cover above the transmitters, but we always had transmitters attached at the base of a sturdy, live tree, meaning there was always some degree of obstruction of the sky above the transmitter. Further, we did not try to ascertain the amount of cover that would interfere with transmitter communication. Nevertheless, we observed it was important to make certain the transmitters had as clear and unobstructed view of the sky as possible.

Because these transmitters need a clear view of the sky and therefore cannot be buried or hidden in extremely dense vegetation, animal wariness to the transmitter could be a concern. We saw no adverse effects to having the transmitter present in our mountain lion sets. However, this was expected, as felids are generally much less particular about trap site presentation than some other species. We suspect canids would be particularly hesitant and suspicious if the trap transmitter was in clear view or near the trap. This concern is species and situation specific, and should be a consideration for anyone considering using satellite trap transmitters. Options to hide the transmitter could include placing the transmitter up a tree or fence post and attaching it to the trap via a longer piece of wire and guiding screw eyelets. Or, if trapping in a prairie or desert habitat, the transmitter could be staked into the ground as far away as needed, with a longer length of wire or cable used to attach the pin and trap. If used in conjunction with box-type traps, the transmitter could be easily attached and concealed on the roof of the trap.

We recognize our sample size of nine captures is relatively small, and our results should not be interpreted as an exhaustive account of using satellite trap transmitters. However, we believe our experiences with these trap transmitters are informative, and from them, we offer several recommendations. First, we often deployed transmitters in situations with a light to medium degree of cover, and they generally performed well. However, our observation over the course of the study was that sites with the least amount of obstruction (cover or topography) consistently had better daily status email success rates as well as faster capture notifications. Therefore, site selection is crucial for proper satellite communication and transmitter function and should be of utmost concern. Second, we believe these transmitters could be used to monitor traps set for extended periods of time (several days to a week), allowing for extended time between physical checks (e.g., from daily to perhaps biweekly or weekly). The length of time between physical trap checks will depend upon the situation and the animal welfare protocols approved for the project. Unfortunately, we also experienced equipment failures during our study, so we advise anyone who plans to use this type of transmitter to first build trust in their individual transmitters and their specific method of use before being dependent upon them. Additionally, we recommend checking the transmitter function any time you deploy one, ideally via a test trigger. Random follow up test-triggers are a good idea as well, especially if a transmitter has not sent a status email for several days. Third, when purchasing transmitters, we recommend equipping them with a very high frequency (VHF) radio beacon, if available. Even though this feature may decrease battery life, we found this feature to be a useful way to verify that the unit was functioning properly, and it could also be used as a backup alarm system. Fourth, we found it beneficial to forward capture messages to our cell phones, which allowed crew members to monitor traps continuously as long as they had cell phone service. Finally, we recommend resetting transmitters early in the day whenever possible and perhaps even recording these times. The daily status messages came 24 hours after the transmitters were reset and stayed on that schedule until they were reset again. Receiving daily status emails at a predictable time at the beginning of the day ensured we had time available to check any trap site if the need arose. We believe satellite trap transmitters represent a valuable development in the world of trap monitoring, and they may find use in other areas as well, such as monitoring den emergence or disturbance of carcasses/baits.

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