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RH: Beaver transmitters • Baker

Efficacy of tail-mounted transmitters for beaver

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Beaver (*Castor canadensis*) are semi-aquatic mammals that usually spend daylight hours inside lodges or bank dens and may be confined under the ice in ponds during winter, characteristics which make radiotelemetry very useful for life history studies (Baker and Hill 2003). Neck collars are not suitable because beaver have fusiform bodies with thick necks that cause collars to easily fall off. Intraperitoneal implantation of transmitters (implants) has been the method of choice since first used for beaver in the 1980s, but they also have problems. Implants require surgery via a dorsal (Davis et al. 1984), ventral-lateral (Wheatley 1997), or ventral-midline (Ranheim et al. 2004) incision. Surgery can increase mortality rates and cause logistical and ethical concerns. The signal range of implants is less than external transmitters because the body attenuates the signal and because the coiled antennas used for implants are less efficient than external whip

antennas. Thus, external transmitters may be more desirable than implants, if a successful attachment method can be found.

Beaver have large, flat tails composed of dense adipose tissue, a central tailbone, and tough, scaly skin. Tails vary greatly in size among and within individuals, depending on their age and condition. Collars placed around the base of tails are problematic because they can slip off narrow tails or tails that decrease in size following attachment (Bruce W. Baker unpublished data). Rothmeyer et al. (2002) developed a new tail-mounted radio transmitter for beaver using a modified livestock ear tag that was attached via a hole drilled through the tail. Comparisons among implants, tail collars, and modified ear-tag transmitters showed that modified ear-tag transmitters had the greatest efficacy in their study of translocated beaver in Wyoming. But they also found the average retention time of modified ear-tag transmitters (hereafter tail-mounted transmitters) was only 104 days (range 5 – 503 days). Because these transmitters were recovered from upland sites, they suggested translocated beaver that lacked established ponds and lodges may have had higher predation rates and greater opportunity for transmitters to be torn from the tail (McKinstry and Anderson 2002, Rothmeyer et al. 2002). Thus, transmitter retention time should be longer in studies of resident beaver.

Here, I evaluate the efficacy of tail-mounted transmitters in a life history study of resident beaver at Rocky Mountain National Park (RMNP), Colorado.

Study Area

Beaver populations in RMNP declined dramatically in the 1940s and have failed to recover since then. A beaver life history study was initiated in August 2001 to help explain these patterns, in addition to concurrent beaver habitat studies (Baker et al. *In*

press). Willow (*Salix monticola*, *S. geyeriana*, *S. planifolia*) dominated most of the active beaver sites, which included Wild Basin, Boulder Brook, Hollowell Park, Big Thompson River, and Endo Valley. Beaver were largely absent from Moraine Park, Horseshoe Park, and Beaver Meadows where intense elk (*Castor canadensis*) browsing had severely hedged willow plants. The exception was a single beaver colony that persisted in Moraine Park within and near several elk exclosures. Most beaver territories included several lodges, bank dens, dams, and ponds. Ponds and most stream sections were covered with ice during November – March. The terrain was very mountainous with steep ridges that separated east-west trending valleys.

Methods

Thirty-four beaver were trapped in Hancock and box (1 kit, 1 adult) traps from streams on the east slope of the continental divide, which likely represented 80 – 90% of the east slope population in RMNP. Transmitters were attached to the tail using the methods provided by Rothmeyer et al. (2002), with some modifications. Instead of using a capture pole to restrain beaver, beaver were placed inside burlap sacks before removal from Hancock traps by working a sack through the gap at the back of the trap. Sacked beaver were removed from the trap, weighed, and the tail was exposed while someone gently kneeled over the beaver to prevent movement. A second person used a large caliper to locate a spot on the tail that (1) equaled the 10 mm depth of the transmitter attachment post or was the thickest spot available on thin tails and (2) was the greatest distance from the edge of the tail, nearest to the base of the tail, and not within 3 cm of the midline to avoid the tail bone and blood vessels. A 5 mm diameter hole was drilled through the tail with a sterilized bit and anesthetic/analgesic was applied to the post and

hole to prevent infection and ease pain during healing. Injected analgesic was not used before drilling because the adipose tissue of the tail was too dense to absorb liquid. A Passive Integrated Transponder (PIT) tag was placed under the skin on the back about 2 cm anterior to the dorsal surface of the tail base. A foam spacer was glued to some transmitters when the available tail area was too thin to fill the transmitter post depth. Blood samples were drawn via a blind stick method on the dorsal surface of the tail 1 – 2 cm posterior to the hairline and 3 – 5 mm lateral to the midline. Blood was lab-tested and found negative for tularemia (*Francisella tularensis*) and plague (*Yersinia pestis*), and was used to develop a new genetic method of gender determination for beaver (Williams et al. *In press*). Beaver gender was determined in the field via anal gland secretion (Schulte et al. 1995) and palpation for the baculum, and later confirmed or corrected (in 4 cases) in the lab via the new genetic method (19 male, 15 female). Body mass was used to separate the 34 captured beaver into 2 age classes for this analysis; body mass was 3.2 – 5.2 kg for 12 kits (< 1 year) and 8.6 – 22.3 kg for 22 adults (> 1 year). Kits also had much smaller tails than adults. All beaver were processed and released at capture sites, which took 30 – 60 minutes/individual.

Transmitters were made by Advanced Telemetry Systems (ATS, Isanti, Minnesota) and were 2 different sizes (Fig 1). Large transmitters (Model M3530) were similar to those used by Rothmeyer et al. (2002) and had pulse rate of 40 pulses/minute (ppm), a weight of 36.5 g with the attachment post, and an expected battery life of 558 days. Large transmitters had a mortality switch (pulse rate 80 ppm) that engaged after 6 hours without movement and an activity switch (pulse rate varied with activity level) that engaged when transmitters were moving. A smaller transmitter (Model M3520) was

designed by ATS after a large transmitter tore from the tail of a 3.2-kg kit only 2 days after attachment. Small transmitters were attached only to kits and had a pulse rate of 40 ppm, a weight 18.8 g with attachment post, an expected battery life of 349 days, a 12-hour duty cycle, a 6-hour mortality switch, and no activity switch. The dimensions (thickness $\times$ width $\times$ length) were $6 \times 7 \times 7$ mm for small transmitters and $6 \times 11 \times 18$ mm for large transmitters; their attachment systems were identical.

During 13 August – 20 November 2001, transmitters were attached to 34 first-captured beaver and 7 recaptured beaver after transmitters had torn loose in Hancock traps or the hole in the tail had enlarged and the transmitter was moved to a new spot on the tail. Observers used 3- or 4-element hand-held Yagi antennas to locate signals, usually once or twice weekly, from 13 August 2001 to 6 August 2003; date, time, signal location, and signal type (inactive, active, or mortality) were recorded. If a mortality signal was received, then observers attempted to recover the radio and determine the outcome. No attempt was made to recover radios that were deep inside active beaver lodges because digging into active lodges would cause beaver to temporarily or permanently abandon lodges and increase their risk of predation, which could affect beaver mortality and dispersal data. If active lodges became inactive, and transmitter signals came from the edge of lodges, then transmitters were recovered with minimal disturbance to lodges. Thus, the cause of mortality signals located inside most beaver lodges could not be confirmed as either detached transmitters or dead beaver. Transmitter retention time was calculated by taking the difference between the attachment date and the midpoint between (1) the last date an active or an inactive signal was detected and (2) the first date a definite mortality signal was detected.

Results

Tail-mounted transmitters were very easy to attach to beaver at the capture site using the methods provided by Rothmeyer et al. (2002) and some modifications. Most beaver were docile while in the burlap sack and did not react to the drill or transmitter attachment except to try to move forward in the sack. A few beaver struggled to escape. One adult male that appeared healthy in the trap died unexpectedly during processing and 1 adult female that appeared distressed in the trap died shortly after release from rapid processing, but necropsies were inconclusive regarding cause of death. A fixed-length attachment post relative to highly variable tail dimensions resulted in attachments that were sometimes close to the edge of tail or were loose on thin tails. The foam backing that was used to create a tighter fit on some thin tails was either worn away or water-logged and compressed on recovered transmitters, which suggests it was an ineffective modification.

The 41 transmitter attachments had the following outcomes. One transmitter was found after 119 days at an upland site where tracks and drag marks in the snow indicated coyote (*Canis latrans*) predation on the adult beaver. One transmitter was found after 332 days still attached to an adult beaver inside a bank den, which had died of unknown causes. One transmitter failed after 94 days when the signal clicked and then quit and 1 transmitter failed after 499 days when the signal weakened and then quit. One large transmitter was removed by observers after 5 days on a kit and replaced with a small transmitter and 1 transmitter was moved to a new location on the tail after 32 days because the attachment hole in the tail had become enlarged. Four of 20 beaver that were recaptured in Hancock traps after 1, 33, 49, and 55 days had transmitters that became

detached during capture; all transmitters were reattached to a different location on the tail. One transmitter switched to mortality mode after 130 days, but power line interference with the signal precluded recovery and outcome confirmation. Nine transmitters switched to mortality mode after 9, 15, 41, 76, 86, 200, 224, 239, and 278 days, but recovery and outcome confirmation were precluded because signals came from inside active beaver lodges. Twenty-one transmitters that switched to mortality mode were confirmed as detached from the tail without evidence of beaver mortality, either when transmitters were recovered (20 cases) or the beaver was recaptured without its transmitter (1 case).

Nineteen of 21 transmitters became detached before they reached their expected battery life (Fig. 1). Retention time averaged 96 days and 41 days for 4 small and 4 large transmitters, respectively, on 8 kits, and 276 days for 13 large transmitters on adults. None of the 4 large transmitters on kits were retained > 60 days. Two small transmitters were retained on kits for 159 days, which was still less than half of their expected battery life of 349 days. Two of 13 large transmitters on adults were retained and still functional about 2 months longer than their expected battery life of 558 days; in contrast, 2 others were retained only 6 and 16 days.

Recovered transmitters were found inside bank dens, at the edge of beaver lodges, in stream channels, on beaver dams, or in food caches. Where transmitters were recovered in beaver lodges and bank dens, they were usually found near or within a tangled mass of beaver-cut sticks that often lined the entrances. Transmitters were often found by probing burrows with a hand or a stick to attempt to move the transmitter and switch the signal from mortality mode (80 ppm) to active or inactive mode. Small

transmitters lacked activity switches and were much more difficult to recover because after they were moved once further movement did not change the signal. Large transmitters had activity switches that increased pulse rate each time they were moved, which made them much easier to find within confined underground burrows and lodges.

The condition of recovered transmitters varied greatly and sometimes revealed how they became detached (Fig. 2). Entire antennas were missing and likely chewed-off on 11 of 18 detached transmitters (Fig. 2 A – K; 2 recovered transmitters missing) and antennas were intact on 7 others (Fig. 2 L – R). The post and button attachment system was intact on 11 of 18 detached transmitters (Fig. 2 A, F – N, Q – R), which indicates they likely became detached when the hole in the tail enlarged or the tail tore from the attachment hole to the edge. The button portion of the post, which prevented the post from pulling through the attachment hole, was partly or completely missing on 3 detached transmitters (Fig. 2 D, E, P). The transmitter base plate was broken on 1 detached transmitter (Fig. 2O) and chewed-off on 1 detached transmitter (Fig. 2C). The 2 transmitters that remained attached until the beaver's death both had missing antennas (Fig. 2 A – B); the attachment system was intact but the epoxy had been broken by biting, likely by a coyote, on 1 transmitter (Fig. 2A; coyote predation) and the attachment button was partly broken on 1 transmitter (Fig. 2B; unknown cause of death).

Signal detection distance varied due to location of the beaver, topography, and presence or absence of the transmitter antenna. Most radiotracking occurred during daylight hours when beaver were in burrows or lodges, which usually attenuated signals and reduced range to 100 – 200 m. Signal range was also reduced by about one-half when antennas were chewed-off by beaver. Maximum signal range was 1 km when observers

on the ground were elevated by topography (< 200 m), transmitters were outside of burrows, and transmitter antennas were intact. Although the terrain was very mountainous most beaver stayed within relatively small territories in separate valleys, which facilitated radiotracking.

In spite of the problems encountered with tail-mounted transmitters, the use of telemetry yielded knowledge that was not evident from previous field studies. For example, biologists in RMNP have historically estimated beaver population size by multiplying the number of active lodges by 6 individuals. Radiotracking data from this study suggested this method likely overestimated population size, as telemetry confirmed active lodges contained 1– 6 individuals and multiple active lodges or bank dens were often used by the same individual (B. W. Baker unpublished data).

Discussion

Tail-mounted transmitters on beaver were easy to attach and the signal range was good with intact antennas, but antennas were missing and likely chewed-off by beaver on 13 of 20 recovered transmitters. Transmitters had much shorter than expected retention time, which was less than expected battery life in 19 of 21 cases and less than 60 days in 8 of 21 cases (Fig. 1). The outcome was uncertain for 9 transmitters that emitted mortality signals from locations that prevented transmitter recovery, such as active beaver lodges.

Rothmeyer et al. (2002:427) found retention time averaged 104 days for 44 beaver in Wyoming and suggested that “low retention times and high variance were due to the high mortality of translocated beavers (36%).” Beaver in their study weighed 2.7 kg – 25.8 kg, which was similar to the 3.2 – 22.3 kg weight of kits and adults in this

study. Retention time for the combined kit and adult data ($n = 217$) in this study averaged 197 days, about twice as long as their Wyoming study. Radiotracking data in this study showed most beaver were residents that had small territories of < 2 ha and used multiple lodges and bank dens. The only exception was an adult male beaver that dispersed about 7 km downstream of its capture site, which may not have been found without the stronger signal strength of tail-mounted transmitters. Recovery of detached transmitters showed that established lodges and bank dens contained a large number of protruding sticks and roots within confined spaces, which provided ample opportunities for transmitters to catch and tear free of the tail. Data from this study supports the assumption of Rothmeyer et al. (2002) that transmitters found detached in upland sites are likely predation events and transmitters found detached in wetland sites likely represent tear-outs from live beaver.

The inability to recover some transmitters that emitted mortality signals from inside active lodges was frustrating. A major objective of the study was to determine the rate and cause of beaver mortality. A transmitter in mortality mode with an unknown cause was a failure to meet this objective, which occurred in 9 cases when signals came from inside active beaver lodges. In addition, the high incidence of false mortality signals led observers to suspect that all mortality signals from dens and lodges were the result of detached transmitters. This assumption was incorrect in 1 case when mortality signals from a bank den eventually led observers to find a dead beaver within the formerly active bank den. Observers also had other difficulties interpreting mortality signals. Sometimes observers recorded a series of inactive or active signals from beaver inside lodges for several weeks, then 1 or more mortality signals on successive visits, then back to inactive

or active signals. In some cases it appeared that mortality switches were triggered by beaver that had not moved for > 6 hours, and in other cases it appeared detached transmitters on mortality mode were bumped by beaver moving inside lodges that caused transmitters to reset back to inactive or active mode. In some cases beaver appeared to move inside lodges as observers approached, which triggered a change in signal. Unfortunately, these assumptions were impossible to confirm. Beaver in this study had been implanted with PIT tags, but it was not possible to identify the tag on a live beaver or use other cues to positively identify beaver observed after transmitters had detached. However, in a Massachusetts study observers visually confirmed active beaver with similar tail-mounted transmitters in mortality mode (Kiana Koenen personal communication). The use of implants for beaver would largely solve the problem of false mortality signals if they included a thermistor to detect loss in body temperature when animals die (Chris Kochanny personal communication).

What modifications might improve transmitter retention and function? Rothmeyer et al. (2002) suggested several ideas based in part on preliminary results from this study, including a bolt inside a hollow sleeve to reduce enlargement of the attachment hole. The condition of recovered transmitters in this study suggests some additional ideas. A steel tube to encase the antenna wire near the transmitter, or thicker antenna wire, might prevent beaver from chewing off the entire antenna, as they did with 11 transmitters in this study. A bolt, washer, and nut would permit transmitter attachment to thicker portions of the tail and a tighter fit, which might reduce transmitter loss due to broken plastic posts and to tear-outs. This attachment method was successful for 2 Eurasian beaver (*Castor fiber*) in Norway (Sharpe and Rosell 2003). A 2003 version of the Model

M3530 transmitter used an adjustable depth attachment post with promising results in Massachusetts (Chris Kochanny, ATS, personnel communication). In 2004, the National Wildlife Research Center (USDA/APHIS/WS) was testing several different transmitter designs via captive and non-captive beaver (Wendy Arjo personnel communication). Thus, others continue to search for more effective tail-mounted transmitters for beaver.

In conclusion, tail-mounted transmitters for beaver had some success in this beaver life history study but are not recommended for long-term monitoring without significant modifications to the original design. Hopefully, the efficacy of tail-mounted transmitters will improve as successive versions are developed because the flat tail of a beaver is a very convenient place to attach a transmitter.

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Figure Legend

Figure 1. Retention times for 21 tail-mounted transmitters confirmed as detached from the tails of beaver without evidence of mortality. Expected battery life was 349 days for small transmitters and 558 days for large transmitters. Most large transmitters were retained longer than most small transmitters, but no small transmitters were placed on adult beaver.

Figure 2. The condition of 18 recovered transmitters varied greatly and sometimes revealed how they became detached from the tails of beaver. Transmitter's A – B were retained until death by predation (A) or unknown causes (B) and transmitter's C – R detached from the tails of beaver without evidence of mortality. Transmitter's K, Q, and R were small-sized models placed only on kits and the others were large-sized models placed on adults and some kits. Transmitter's D, E, and P were inverted to show the broken attachment button. Transmitter R was inverted to show the compressed and torn foam backing (just above the address label) used as a spacer on thin beaver tails.