Estimating Retention Rates of Leather Spacers on Radio Collars for Black Bears in Georgia

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Abstract: We used known–fate analysis in Program MARK to estimate retention rates for radio collars equipped with leather spacers on American black bears (*Ursus americanus*). We radio collared 72 bears 81 times in the Upper Coastal Plain of middle Georgia along the Ocmulgee River. For the 59 spacers that broke, they lasted an average of 365.5 days (SE = 31.3, 38–782) for males and 519.2 days (SE = 63.4, 139–1482) for females. Retention rate for leather spacers varied by month and sex ($\bar{x}$ = 0.8736, SE = 0.0390, n = 50 for males and $\bar{x}$ = 0.9391, SE = 0.0231, n = 50 for females). Leather spacers did not last as long on males, averaging 1 year but broke early enough to avoid injuries. Females tended to retain spacers for longer periods, allowing researchers to obtain greater data without having to re–collar them annually.

Key words: black bear, breakaway radio collar, Georgia, Ocmulgee River, *Ursus americanus*

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Radio telemetry is an important component of many wildlife research studies and transmitters have been attached by numerous methods including implantation, backpacks, glue, and collars. Radio transmitters are often attached to large terrestrial mammals with collars, especially American black bears (*Ursus americanus*; henceforth bears; Garshelis and McLaughlin 1998). Researchers need to consider many factors when using collars on animals including the species of study, weight and age of the study animals, and the duration of collar attachment. Radio collars can cause abrasions, cuts, and mortality (Servheen et al. 1981, Strathearn et al. 1984). Collars need to fit snugly to prevent premature removal; however, neck growth of young animals and seasonal weight fluctuations in adults may lead to neck injuries (Servheen et al. 1981, Strathearn et al. 1984). Breakaway mechanisms allowing collar detachment after a period of time have been developed to minimize neck injuries to black bears (Hellgren et al. 1988, Seibert and Wooding 1994, Garshelis and McLaughlin 1998) and easy retrieval of the collar and data if GPS collars are used (i.e., the animal does not have to be recaptured). Several designs of collars have been used on other mammal species to minimize neck discomfort: bobcats (*Felis rufus*; Jackson et al. 1985), ungulates (Hamilton 1962, Kolz and Johnson 1980), pronghorn (*Antliocapra americana*; Beale and Smith 1973), mountain lion (*Felis concolor*; Garcelon 1977), and sea otters (*Enhydra lutris*; Loughlin 1980).

Hellgren et al. (1988) and Koehler et al. (2001) used cotton breakaway spacers (12–15 cm in length) between the ends of the collar to minimize discomfort and injuries to bears. Seibert and Wooding (1994) evaluated surgical tubing (i.e, rubber) and leather materials. Garshelis and McLaughlin (1998) used oiled leather spacers in Minnesota and un–oiled leather spacers in Maine.

We used oiled leather spacers in our study of collar retention by bears in a wetland environment in middle Georgia because Hellgren et al. (1988) observed that in hot, humid climates cotton spacers had a shorter longevity as did rubber (i.e., surgical tubing, Seibert and Wooding 1994) in Florida. Hellgren et al. (1988) recommended using leather spacers. Seibert and Wooding (1994) and Garshelis and McLaughlin (1998) had success using leather spacers. Our objectives were to determine the longevity and monthly retention rates of these leather spacers deployed on radio collars for black bears in Georgia.

Methods

We monitored bears in portions of Bleckley, Houston, Laurens, Pulaski, and Twiggs counties (137,305 ha) in the Upper Coastal Plain physiographic region of Georgia. Most of our bear trapping effort occurred on Oaky Woods (7,851 ha) and Ocmulgee (8,597 ha) Wildlife Management Areas (WMA) with additional trapping on proximal private properties; therefore, the trapped area was composed of 29% wetlands (forested = 23%, open water = 1%, emergent = 1%, and shrub/scrub = 4%; GDNR 1996, NWI 1999) along the Ocmulgee River. During our study, mean annual temperature ranged from 17.3 to 18.0 C while annual rainfall ranged from 95.3 to 136.8 cm (NCDC 2008).

We annually trapped bears using Fremont bear foot snares from April through August (some exceptions occurred), 2003 through 2006. We anesthetized bears using a mixed dosage of 4.4 mg/kg of ketamine HCL (Ketaset, Burns Veterinary Supply Incorporated, Farmers Branch, Texas) and 2.0 mg/kg of xylazine HCL (Rompun, Haver–Lockhart Incorporated, Shawnee, Kansas; Kreeger 1996). Bears were fitted with a 650 g VHF radio telemetry collars (51 mm wide; Advanced Telemetry Systems [ATS], Inc., Isanti, Minnesota; use of trade name does not imply endorsement by the DNR) equipped with mortality and activity sensors. We attached leather spacers between the two loose ends of the collar using two double bolt arrays with 25-mm bolts, a flat washer and a 8-mm nylock locking nut supplied by ATS (Figures 1 and 2). Garshelis and McLaughlin (1998) soaked their leather spacers in boot oil for <30 min until saturation and their spacers were 4.5–5.5 mm thick, 4 cm wide and 8 cm in length. Our spacers were 4 mm thick, 4cm wide and 8.9 cm in length, slightly thinner and longer than those used by Garshelis and McLaughlin (1998) and we soaked the leather spacers in vegetable oil for >1 month prior to attachment believing the vegetable oil would allow the spacers to be pliable, durable, and increase longevity up to a year but not to an extent that would cause injuries. We monitored bears most of the time once per week. Typically we were able to examine bear mortalities within a week.

We defined spacer longevity as the number of days the spacer remained unbroken and the collars remained attached to the bear, which was the sole metric that has been reported in the literature. We calculated average spacer longevity for all spacers combined and by sex of the bear. We used a Wilcoxon rank sum test (Ott 1988) to test for sex–specific differences in spacer longevity because our data were not normally distributed and violated the assumptions of a *t*–test. The Wilcoxon rank sum test was the more informative test and was more likely to declare a difference when it exists (Ott 1988).

Unfortunately, data from collars that fail, have spacers replaced, or signals are lost prior to spacer breakage cannot be used to estimate average longevity. Also, average longevity does not adequately represent the increasing probability of breakage as the spacer ages. Therefore, we used known–fate analysis to estimate monthly spacer retention rate (the probability that a spacer will remain functional during a given month). In so doing, monthly data from all spacers can be included in the analysis even though the collars might have failed, been lost, or had intact spacers replaced at some point in the past.

For the spacer retention analysis, data were organized into the capture history format common to Program MARK with each

Figure 1. Black bear radio collared with a leather breakaway spacer in Georgia.

Figure 2. Radio collar dropped by a black bear with a broken leather spacer in Georgia.

two–column period representing one month. Capture histories were structurally analogous to the live–dead (LD) format defined in Cooch and White (2007). Data were divided into two groups by sex, and the number of spacers and their fates was tabulated monthly. We tested by sex because spacer longevity has been believed to vary by sex of the bear (Hellgren at al. 1988, Seibert and Wooding 1994, and Garshelis and McLaughlin 1998). We set the month when the bears were initially collared or when spacers were replaced as the starting dates for our retention analyses. We used Program MARK (White and Burnham 1999) to estimate monthly retention rates (*S*) using five competing models: a constant retention rate (.), a time–variable retention rate (t), a sex–specific retention rate (g), and a sex by time retention rate with interaction (g*t) and without interaction (g+t). We assessed models using relative Akaike's Information Criterion adjusted for sample size and lack of fit ($\Delta QAIC_c$) scores and Akaike weights (Burnham and Anderson 2002).

We used a Gompertz model (Gompertz 1825) to fit a curve to the cumulative retention rates because Gompertz models are widely used in ecology (Batschelet 1976) and may perform better than logistic equations in some instances (Berger 1981). The Gompertz model has a formula of $y = ae^{be\wedge cx}$. We used Program R version 2.6.2 to generate the parameter estimates for the Gompertz model that describes sigmoid shape of the cumulative retention rate curves for males and females (R Foundation for Statistical Computing, Vienna, Austria).

Results

We collared 72 bears (males = 3.9 mean years of age, mean mass of 99.6 kg, $n = 42$; females = 6.0 mean years of age, mean mass of 56.2 kg, $n = 30$), re–collared 4 bears and replaced 5 spacers for a total of 81 spacers (Table 1). Spacers broke between 2003 and 2008. Of the 24 different instances we had to document collar injuries (i.e, bears we could re–examine; recaptured [$n = 15$], road killed [$n = 5$], or died from other reasons [$n = 4$]), we observed no instance of potential injury from the collar.

We could not use 22 spacers to calculate spacer longevity (road mortality, $n = 5$; replaced leather spacers, $n = 5$; slipped collars, $n = 4$; transmitter failure, $n = 4$; and mortalities, $n = 4$; Table 1). Spacer longevity was lower ($z_{59} = 2.014$, $P = 0.044$) for males ($\bar{x} = 365.5$ days SE = 31.3, range 38–782 days, $n = 35$) than females ($\bar{x} = 519.2$ days SE = 63.4, range 139–1482 days, $n = 24$).

For the known–fate spacer retention analysis, all 81 spacers were included. Program MARK indicated that there was model selection uncertainty ($\Delta QAIC_c = 1.29$) between the two top models: *S*(g*t) and *S*(g+t), indicating that retention rates varied by sex of bear and by month, but there may or may not be interaction between the effects of sex of bear and month on retention rates. Based on a $QAIC_c$ weight of 0.6499 and a model likelihood of 1.00, the model that best fit the data was *S*(g*t) which included interaction. The second best model, S(g+t), had a weight of 0.3409 and a model likelihood of 0.5246. Using the top weighted model, there were 50 monthly retention rate estimates for males that averaged 0.8736 (SE = 0.0390; range 0.139E–10 to 1.0) and for females that averaged 0.9391 (SE = 0.0231; range 0.161E–05 to 1.0). Given the low model likelihood scores and $QAIC_c$ weights of the other models, we believe that there was little evidence for a retention rate that was constant or varied by month or sex alone. Percentage of broken spacers for males were 48.4% at 13 months, 73.3% at 17 months, and 86.6% at 24 months and for females were 47.7% at 18 months, 72.3% at 32 months, and 90.8% at month 49 (Figure 3). Cumulative retention rates for both males and females are sigmoidal in shape (Figure 3). The curves can be described by a Gompertz model with the formula: retention rate = $ae^{be\wedge c*month}$ where e = base of the natural logarithm (2.718282), month = number of months since collar was attached, and for males a = 136.80, b = –0.2386, c = 0.1075, and for females a = 265.78, b = –0.8625, and c = 0.0338. The Gompertz curves were strongly correlated to the actual data: r = 0.9965 for males and r = 0.9920 for females.

Table 1. Fate of radio collars used on black bears (*Ursus americanus*) in Georgia, 2003–2008.

	Males	Females	Total
Collared	42	30	72
Re–captures	9	6	15
No action	4	2	6
Re–collared	4	0	4
Replaced spacer (censored)	1	4	5
Broken spacer	35	24	59
Slipped collar (censored)	3	1	4
Transmitter failure (censored)	1	3	4
Road–mortalities (censored)	4	1	5
Other mortalities (censored)	3	1	4

Discussion

On long–lived species (e.g., bears), researchers often use breakaway devices to minimize injury and to account for weight fluctuations (Hellgren et al. 1988, Seibert and Wooding 1994, and Garshelis and McLaughlin 1998). Koehler et al. (2001) reported three bears (8.8%; out of 34 instances) with neck injuries from collars using cotton spacers, Garshelis and McLaughlin (1998) reported that 3% (23/672 bears) of bears in Maine experienced neck injury due to large weight gains in autumn using leather spacers, and Hellgren et al. (1988) reported two cases of neck lacerations caused by collars using cotton spacers. Neither we nor Seibert and Wooding (1994) observed any injuries from collars using leather spacers.

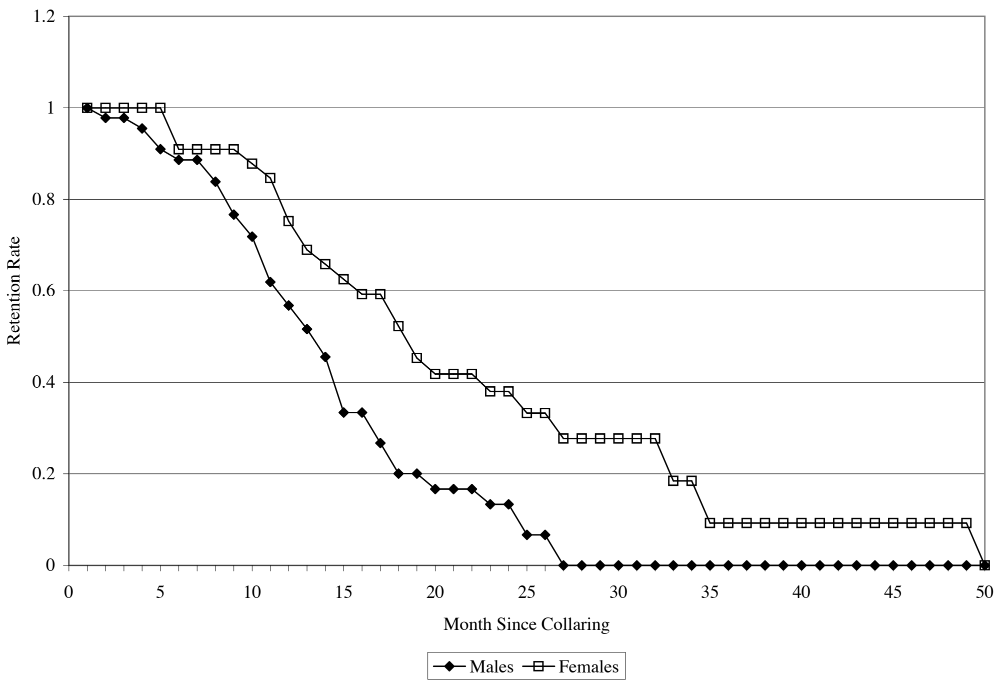

Figure 3. Cumulative monthly retention rates by sex of breakaway leather spacers on black bear radio collars in Georgia 2003–2008.

Our mean longevity for leather spacers was 365.5 days for males and 519.2 days for females. Our female mean longevity was greater than means reported for sexes combined by Seibert and Wooding (1994) for leather spacers (399 days) or surgical tubing (185 days), Hellgren et al. (1988) for cotton spacers on females in an wetland environment (261 days), and sexes combined by Koehler et al. (2001) for cotton spacers in a forested area with 200 cm annual precipitation (10months); however, our female mean longevity was similar to Hellgren et al. (1988) for cotton spacers on females in deciduous forest habitat (548 days) and was less than sexes combined by Koehler et al. (2001) for cotton spacers in a forested area with 52 cm annual precipitation (21 months). Our male mean longevity was greater than the mean reported by Seibert and Wooding (1994) for surgical tubing (185 days), by Hellgren et al. (1988) for cotton spacers on males in an wetland environment (203 days) and in deciduous forest habitat (231 days), and sexes combined by Koehler et al. (2001) for cotton spacers in an forested area with 200 cm annual precipitation (10 months); however, our male mean longevity was similar to Seibert and Wooding (1994) for leather spacers (399 days) and was less than sexes combined by Koehler et al. (2001) for cotton spacers in an forested area with 52 cm annual precipitation (21 months).

Hellgren et al. (1988) observed that longevity of spacers on bears varied by sex. Seibert and Wooding (1994) believed that variations in longevity were gender dependent as well, but did not analyze their data between sexes, most likely due to sample size limitations. Similarly, Garshelis and McLaughlin (1998) believed gender–related differences in spacer breakage existed, but no analysis was conducted. We agree with Hellgren et al. (1988), that male behavior (e.g., travel farther, fight, mark trees, and significant body weight gain) contributed to the shorter longevity of their spacers.

Our study was the first to evaluate spacers on black bears using known–fate retention analysis methods. This analysis supports the results of the longevity analysis that females tend to keep their spacers for a longer time. Additionally, the known–fate analysis showed that spacer retention rates varied by month since collaring as well as sex of the bear. By using the monthly retention rates to build a cumulative retention rate curve and fitting a Gompertz model to the curve, researchers can see and predict how their spacers will perform over time. As expected, the cumulative retention curves indicated that the retention rates were high in the early months followed by a period of lower retention rates as the spacers became worn. Garshelis and McLaughlin (1998) reported that 95% of their collars were either replaced on schedule or the bear was killed or lost, thus providing no further data on the life of the leather spacer. By using known–fate retention analysis all spacers can be included not just those that broke. Also, the probability that a spacer will remain functional by month can be estimated, which is more useful than mean longevity. For example, we observed that almost half of our spacers were retained to the 13th month for males and the 18th month for females. Our intent was for spacers to be retained for a year and we observed that 56.7% of males and 75.2% of females retained their spacers for a year.

Spacer longevity appears to be impacted by spacer material, environmental factors, bears' weight fluctuations, tightness of collar on the bear (i.e., pressure from the animal is lacking on the breakaway spacer) and sex of the animal, with females in drier habitats tending to retain their spacers for the longest times. We believe leather spacers allow adequate time to collect telemetry data during an annual cycle for both male and female bears in hot, humid wetland environments, while still reducing the chances of collar injuries. We agree with Seibert and Wooding (1994) that leather spacers last longer; however, researchers should consider their research objectives, study duration, bears' size and age, and local environment (e.g. wetlands, precipitation, etc.) in the selection of spacer materials.

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