REVIEW AND EVALUATION OF BREAKAWAY DEVICES FOR BEAR RADIOCOLLARS

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Abstract: Researchers often handle radiocollared bears on an annual basis, so collars can be readjusted. However, if a collar cannot be refitted (as when a bear becomes lost to the investigator because of radio transmitter failure), the animal may be subjected to lifelong neck irritation or more serious injury. To prevent this, devices have been developed that enable collars to eventually break away. During 1983–95, we used a piece of vegetable-tanned leather to link the 2 ends of radiocollars on black bears (*Ursus americanus*). The link was intended to break apart in 1–3 years if the bear was not handled and the link changed. We used unoiled links in Maine (n = 756) and oiled links in Minnesota (n = 549), and we set strict standards on the thickness of links used in Minnesota; we found that the Minnesota links were less prone (1%) to breaking off prematurely (<1 year). We also surveyed other bear researchers, 93% of which employed some sort of breakaway device; 13 different breakaway designs were described, of which 4 were commonly used. Of these, a linkage constructed of latex tubing tended to be most prone to premature breakage, whereas leather was least apt to break prematurely; links made of cotton belting or firehose were intermediate in their tendency to break too early. If the link did persist and was not changed in <1 year, an across-study average of about 75% of links made of latex, cotton, and firehose broke as intended, compared to 60% of leather links. However, breakage seemed to be prompted as much by pressure on the link as by weathering; thus, collars that did not break in the prescribed time might not have been tight. Despite the potential for premature breakage of some links and the chance that some last longer than desired, we strongly recommend their use over collars without breakaway devices.

Ursus 10:459–465

Key words: bears, breakaway devices, cotton webbing, firehose, latex tubing, leather link, radiocollar, Ursidae.

Radiocollars have become an integral part of most studies of bears. In 1961, when the first bear was collared (Craighead 1979), and through the ensuing decade (Hensel and Berns 1968, Pelton 1972), primary concerns centered around range and lifespan of the radios. Researchers also worked to devise standards, at least within their own projects, for proper fitting of collars, making them snug enough to not fall off but leaving some room for growth. Inevitably, though, bears grew and some collars got too tight, resulting in injuries to the neck before the animals could be handled again and the collars removed or loosened.

Neck injuries from tight collars must have been rather prevalent during the early 1970s when individual bears typically were not handled on a regular basis. Even with the development of reliable, long-lasting radios and methods that enabled researchers to recapture and refit collars on bears on an annual basis, there remained a concern that collars on some individuals would nonetheless become too tight (e.g., if a radio failed or a bear could not be recaptured or handled in its den). However, we found only 3 published descriptions of bear collars that were designed to break away (Strathearn et al. 1984, Hellgren et al. 1988, Seibert and Wooding 1994). One group of researchers also reported using ear-mounted transmitters as an alternative to collars to avoid problems with neck injury (Servheen et al. 1981).

We began experimenting with breakaway links on radiocollars for black bears in 1983 in Minnesota (DLG) and Maine (CRM). In Minnesota we initially tried a commercially made design (Telonics Inc., Mesa, Ariz.) using latex surgical tubing. When the tubing eventually becomes brittle and breaks, the collar falls off. However, in our study the tubing broke too quickly (often <6 months) even if we wrapped it in tape. Other designs that we tried, including collar belting attached with open-ended rivets wrapped in tape and transmitters epoxied to the hair on the shoulders of bears, also fell off too quickly. In Maine we began using a leather breakaway link on collars, an idea that originated from experience on a Pennsylvania bear study where collars were made of vegetable-tanned leather (other types of tanning can result in neck irritation) that decayed and eventually fell off. This design was adopted in Minnesota.

Our purposes here are twofold: (1) to present data and analyses from our long-term studies using radiocollars with leather breakaway links in Maine and Minnesota, and (2) to compile and summarize data that we obtained from a survey of other researchers on the types and efficacy of breakaway designs that have been used on bears. We were prompted to undertake this task after an episode, involving considerable media attention, in which a colleague attached a radiocollar without a breakaway device to a young bear and the transmitter subsequently failed. Such an episode is harmful not only to the individual bear involved, but also jeopardizes telemetry studies on bears in general, as it may prompt the impression that bear researchers have an uncaring attitude toward

their subjects. Consequently, we felt it would be beneficial, both to researchers and to the bears they study, to assemble and share presently available information on various collar breakaway and expansion devices that have been tried in bear studies.

We thank K.V. Noyce, P.L. Coy, M.A. Caron, R.A. Cross, and L.M. Tudor, who collected field data on breakaway collars in Minnesota and Maine. We greatly appreciate the information, drawings, photographs, and samples of breakaway devices provided by the many biologists who participated in our survey. This study was supported by the Minnesota Department of Natural Resources and the Maine Department of Inland Fisheries and Wildlife, under Federal Aid in Fish and Wildlife Restoration Projects W-67-R and W-82-R.

METHODS

Leather Breakaway Links in Maine and Minnesota

We fitted black bears with radiocollars made of urethane-butyl rubber belting (Telonics Inc., Mesa, Ariz.). We inserted an 8-cm strip of vegetable-tanned leather (12–13 ounce), the same width as the collar (4 cm), as a breakaway link. We punched holes in the link to match the holes punched in the collar belting and attached it to the short end of the collar using standard collar hardware. After putting the collar around the bear's neck, we attached the long end to the free end of the leather with another piece of hardware. Breakage of the leather link thus enabled the collar to fall off the bear.

We used these links in Maine during 1983–95 and in Minnesota during 1984–95. In Maine we used them on female bears of all ages (males were not collared). In Minnesota we used them on all males and on females that were still growing. We changed links approximately annually when we handled bears in dens or sooner if we trapped them during the summer; thus, we expected them to last at least from 1 year's den to the next.

After the first 2 years of testing in Minnesota, several links broke prematurely (i.e., before the bear denned). Thus, beginning in 1986, in an attempt to retard weathering, we dipped the leather links in boot oil (Neatsfoot compound, Farnam Co., Omaha, Neb.) until they were saturated (<30 min). We also noticed that the thickness of the leather varied somewhat, and links <4.5 mm thick tended to break too early. Thereafter, we measured the leather with calipers and used only pieces that were 4.5–5.5 mm thick.

Breakaway Collars Used in Other Studies

We sent survey forms to other bear researchers involved in telemetry studies requesting information about breakaway or expandable radiocollars. We asked for data about the following: (1) the number of bears radiocollared during the study and the number presently collared, (2) the type of breakaway device used (if any), (3) the source for the breakaway design, (4) the year the study was initiated and the year when breakaways were first employed, (5) the sex and ages of bears on which breakaway collars were used, (6) the expected lifespan of the breakaway, (7) the percent of collars that broke away earlier than expected, broke away on time, lasted longer than expected, and the percent of links that were replaced (or the bear died) before breaking away, and (8) habitat conditions that might have affected the lifespan of the breakaway device.

RESULTS

Leather Breakaway Links in Maine and Minnesota

We attached 1,305 collars with leather links to bears, 756 in Maine and 549 in Minnesota. In Maine, 24 links broke before the bears could be handled in their dens (3–9 months after attachment) and 4 broke in the den (about 1 year after attachment). Forty-three collared bears were not handled during annual den visits; 23 of these were later observed. Fourteen bears were observed 1–2 years after collar attachment, at which time 1 collar had broken away. Nine other bears were observed >2 years after collar attachment: 4 links had not broken after 2 years, 1 broke at 2–3 years, and 4 had not broken after >3 years (37–50 months). Excluding links that were on for <3 months (since none broke in <3 months), 3% broke prematurely, 1% lasted too long, 1% broke on time, and 95% were either replaced on schedule (at yearly den visits), or the bear was killed or lost, thus providing no further data on the life of the link (Table 1).

In Minnesota, using oiled leather, 6 links broke prematurely (4–10 months) and 1 broke in the den (at 1 year). We did not handle 23 bears during annual den visits, 17 of which were later captured or observed: the link had broken on 4 of 11 recovered within 2 years and 2 of 6 recovered or observed after 2 years (33–55 months). As above, excluding links that were on for <3 months, 1% broke prematurely, 1% lasted too long, 1% broke at about the right time, and 97% were either replaced or the bear was killed (Table 1).

Table 1. Fates[a] of leather links put on bear radiocollars in Maine and Minnesota, 1983–95. Links used in Minnesota were oiled and the thickness measured (4.5–5.5mm); those in Maine were not oiled and may have varied more in thickness.

	Link replaced or recovered before intended break-off	Link broke prematurely	Link broke as intended	Link lasted too long
Maine				
Females	698	24	6	8
Minnesota				
Males	285	5	4	1
Females	233	1	3	3
Total	518	6	7	4

[a] Links not changed in the den but changed or otherwise recovered the following year (≤2 years after attachment) were tabulated with links that were changed annually and were not considered failures. Links that broke before the bear denned (<1 year after attachment) were considered to have broken prematurely. Links that broke 1–3 years after collar attachment were considered to have performed as intended. Links that remained intact for >3 years were considered to have lasted too long, as were links recovered after 2–3 years that showed no indication of breaking in <3 years.

Five of 6 links that broke prematurely in Minnesota were on male bears (Table 1). Other data also supported a gender-related difference in breakage of links. Before we began oiling links in 1986, 5 had broken prematurely, all of which were worn by males. Additionally, 1 oiled link, not counted in the above data, broke prematurely when a collared male fought and killed another bear. Conceivably, breeding-related fights might be a cause for the breakage of some links, but none of the collar break-offs that we observed (including those with unoiled links) occurred during the main breeding season in early June, when testosterone (and associated aggressive encounters) reached a sharp peak (Garshelis and Hellgren 1994): 2 broke in the den, 1 broke in April, and the rest (n = 14) broke during July–October. Most of the break-offs in Maine also occurred during late summer and fall. We observed no age-related effect for bears whose links broke, either in Minnesota or in Maine.

The links used in Maine, all of which were unoiled and all of which were on females, broke prematurely more often than the oiled links used on females in Minnesota (χ^2 = 6.13, 1 df, P = 0.01; Table 1). Our data were not sufficient to assess whether oiling also tended to cause links to last longer than desired, although this appeared not to be the case: among Minnesota females with oiled links that were not replaced in the den, 3 lasted too long and 3 broke as intended, whereas among females with unoiled links in Maine, 8 lasted too long and 6 broke as intended. However, the thickness of the leather used in Maine also may have varied more than that used in Minnesota, where we measured and excluded pieces that were too thin or too thick. This may have contributed as much to the lifespan of the links as the oiling.

Breakaway Collars in Other Studies

We mailed 101 surveys, of which 61 (60%) were returned; 56 were completed and 5 indicated no experience collaring bears. Another 10 surveys were completed by researchers or students who obtained the form from a colleague or professor.

Researchers that completed questionnaires indicated that they had radiocollared >6,300 bears, including American black bears (≈ 3,700), Asiatic black bears (*U. thibetanus; n* = 59), brown or grizzly bears (*U. arctos; n* ≈ 2,200), sloth bears (*Melursus ursinus; n* = 18), and polar bears (*U. maritimus; n* > 300). At the time of the survey (autumn 1994), >1,150 bears were wearing radiocollars.

One study used implanted transmitters and 70 used externally attached transmitters (69 collars, 1 ear-attachment; note: number of studies exceeds number of returned surveys because some researchers conducted >1 study and our 2 studies are included); 65 studies (93%) employed a breakaway or expandable device on at least some collared bears. Among the 5 researchers that did not use breakaway collars during their study, 2 indicated that they did not know about them, 2 said they feared that breakaway collars would fall off too early and thereby cause loss of data, and 1 put collars only on adult females whose necks were fully grown. Three of these studies were on American black bears, 1 on Asiatic black bears, and 1 on polar bears.

The first expandable–breakaway type of bear collar documented in our survey was employed by J. Rieffenberger (W.Va. Div. Nat. Resour., Elkins, pers. commun., 1994) in 1976. It consisted of an attachment made with rubber bands, intended to last only a few weeks,

which was used on cubs and small yearlings. A similar cub expandable–breakaway collar made of rubber bands and pieces of inner tube was reinvented by Elowe (1987) in 1983. A collar breakaway device consisting of 2 pieces of latex surgical tubing was developed by a commercial radiocollar manufacturer (Telonics, Inc.) and used on bears beginning in 1977 (H. Reynolds, Alas. Dep. Fish and Game, Fairbanks, pers. commun., 1994). A design composed of a swath of cotton webbing material (with grommets spaced for hardware attachment) inserted between the ends of the collar has been used since at least 1978 (C. Servheen, U.S. Fish and Wildl. Serv., Missoula, Mont., pers. commun., 1995), and was described in a publication a decade later (Hellgren et al. 1988); in 1980, B. McLellan (B.C. For. Serv., Revelstoke, pers. commun., 1994) began using non-rubberized firehose in a similar fashion. Degradable leather collars have been used since 1977 (G. Alt, Pa. Game Comm., Moscow, pers. commun., 1994), and we started using the leather link in 1983; however, while preparing this paper we discovered that Elowe (1984) used leather links a year before us. Latex tubing, cotton webbing, firehose, and leather are presently the most commonly-used materials for breakaway links on bear collars (Table 2).

These designs have been passed on among researchers (58% of survey respondents said they used an unpublished, non-commercial design based on information from someone else), and have been independently reinvented (27% of respondents indicated that they invented the link they were using) or modified. For example, instead of purchasing collars with latex-tubing attachments, some researchers have tied the tubing to the ends of the collar (LeCount 1986, Seibert and Wooding 1994) or clamped it under the attachment hardware (Ballard et al. 1993). To extend retention of the collar, researchers have wrapped breakaway links in tape (although B. McLellan, pers. commun., 1994, suggested that this retains moisture, making it rot more quickly), used double links or double-thickness links, or, as in our study, oiled the leather. Others have added elastic or pleated canvas to hold the collar on a little longer after breakage of the main link (Simek 1993; R. Sellers and T. Smith, Alas. Dep. Fish and Game, King Salmon, pers. commun., 1994; H. Reynolds, pers. commun., 1994). Conversely, to hasten breakage, especially on small bears, links have been slit or notched, or attachment hardware soaked in acid to enhance rusting and promote degradation of the leather (Seibert and Wooding 1994).

Table 2. Types of breakaway links used on bear collars as reported by respondents to our 1994 survey ($n = 66$) plus our studies in Maine and Minnesota. Some respondents used >1 kind of link.

Type of breakaway link	Number of studies using link
Cotton webbing	25
Latex tubing	19
Leather	17
Non-rubberized firehose	6
Strathearn[a] design	4
Degradable collar belting	3
Inner tube	3
Rubber bands	2
Wire	2
String	2
Elastic fabric	2
Stitched-on belting	1
Perforations in collar	1

[a] Described by Strathearn et al. (1984).

Several other designs were reported in our survey (Table 2). One, involving stitched-on plastic cross-strips that tear as the collar tightens, was employed initially in 1978 and later described in a publication (Strathearn et al. 1984). However, it was not widely adopted, presumably because of the extensive work involved in making the collar as well as the high rate of premature drop-off. This design is now commercially available (Lotek Engineering Inc., Newmarket, Ont., Can.) and is currently being used by some bear researchers. Other designs include fastening the ends of the collar with wires (D. Huber, Univ. Zagreb, Croatia, pers. commun., 1994; P. Kaczensky, Agric. Univ. Vienna, Hotedrsica, Slovenia, pers. commun., 1995), string sprayed with varnish (P. McConnell, N.J. Div. Fish, Game and Wildl., Hampton, pers. commun., 1994), elastic fabric (R. Sellers, pers. commun., 1994), inner tube (G. Alt, pers. commun., 1994), or a stitched-on piece of belting (LeCount 1986). One design currently being tested involves punching perforations between the main collar adjustment holes, so that as the collar gets tight the hardware should rip to the next hole (T. White, Miss. State Univ., Mississippi State, Miss., pers. commun., 1995). In some cases the belting (e.g., neoprene-impregnated fabric) used by radiocollar manufacturers (e.g., Advanced Telemetry Systems, Isanti, Minn.) may weather to the extent that it becomes brittle and tears off without a breakaway link (D. Garshelis, pers. observ.; P. McConnell, pers. commun., 1994).

Some studies employed collar breakaway links only on selected sex–age groups of bears. On studies that used breakaway links, 32% (20 of 62 responses to this question) did not put them on adult females and 22% did not put them on adult males; 5% did not use them on subadults, but all studies that employed breakaway collars

used them if they collared yearlings (n = 52) or cubs (n = 6). Respondents differed in their opinions of how long breakaway links should last; some indicated that it depended on the sex–age groups being collared, the lifespan of the radio, and whether it was feasible to change collars regularly. Most researchers (38 of 61; 62%) wanted links to last 1–2 years, but shorter for cubs and sometimes longer for adults, especially in circumstances where collars could not be refitted on a regular basis.

Premature breakage of the link was experienced in all but 3 of 47 studies (with sample sizes of >15 bears) that employed breakaways. Of the commonly-used devices, premature breakage occurred most frequently for links made of surgical tubing and collars of Strathearn et al.'s (1984) ladder-type design (Table 3). Leather links appeared to be least susceptible to premature breakage. However, the range among studies in the percent that broke prematurely was wide, indicating that weather and habitat conditions probably affected the life of these links. All studies that experienced ≥50% premature break-offs, using either leather, cotton webbing, or latex tubing, were in wet environments (Table 3). However, not all studies in wet environments had high rates of premature break-off.

In many studies sufficient data were not available to assess whether the breakaway device would have functioned properly because links were changed prior to when they should have broken off, bears died or were lost from the study, studies ended, etc. For breakaway collars that remained on with links unchanged for >1 year, study results varied greatly in the percent that broke on time (Table 3). On average, >75% of collars with links made of latex, cotton, or firehose that were on >1 year broke as intended; the other 25% stayed on too long in the opinion of the researchers involved. Leather links appeared less desirable in this regard, as about 40% of those that were not changed within 1 year did not break away in the intended time (Table 3).

DISCUSSION

More than 90% of the biologists who responded to our survey used breakaway devices on bear collars. However, use of breakaways by the nonrespondents was unknown, and possibly not as high as for those who did respond. Our hope is that this paper prompts those who currently do not use breakaways to do so and also aids in the selection of a design.

None of the breakaway designs functioned as intended all the time: some animals lost their collars prematurely and collars on some animals may have tightened and caused neck injuries when links failed to break. Among the most-commonly used breakaways, some appear more susceptible to breaking too early, whereas others appear more prone to lasting too long. Latex tubing, cotton webbing, and firehose links seem to provide the best safeguards against neck injury, whereas leather links seem to be least likely to break prematurely. In a within-study test, Seibert and Wooding (1994) also found leather to last longer than latex tubing. However, the relative lifespans of the different types of breakaways may be affected by modifications to the basic design (e.g., taping, cutting, varying the thickness of the links, etc.) and habitat conditions specific to each study.

In Maine and Minnesota, where environmental and vegetative conditions were similar, differences in the lifespan of breakaway links appeared to be related to the thickness and treatment of the leather. More desirable and consistent results were obtained in Minnesota, where

Table 3. Fates of most-commonly-used types of breakaway links on bear collars as indicated by respondents to our 1994 survey.

	Broke prematurely[a]				Broke on time[b]			
	$\bar{x}$ (%)	median (%)	range[c] (%)	n	$\bar{x}$ (%)	median (%)	range (%)	n
Strathearn design[d]	50	50	50	2	–	–	–	–
Latex tubing	30	20	4–(47)–83	11	74	75	46–100	6
Cotton webbing	15	10	0–(22)–58	14	77	81	38–100	8
Firehose	9	10	0–16	4	81	77	75–92	3
Leather	9	4	1–(15)–50	11	60	62	0–100	8

[a] Means, medians, ranges among studies, and number of survey respondents that used the link on >15 bears and estimated the percent that broke earlier than intended, based on the criteria of each individual study.
[b] Means, medians, ranges among studies, and number of respondents that used the link on >15 bears and estimated the percent that broke in the desired time interval, of those that were on long enough to assess (broke on time/[broke on time + lasted too long]).
[c] Range of values among studies; middle value in parenthesis represents high end of range excluding studies in wet environments.
[d] Insufficient data for those that broke away on time.

we oiled the leather and used a standard thickness. We suggest that researchers using leather breakaway links adhere to a similar protocol (samples of the leather link available from the authors).

Most materials for producing breakaways are inexpensive and readily available. Cotton webbing links, with grommets spaced to fit hardware on bear collars, are also commercially available (Blue Star, Missoula, Mont.; cost = US$5). Other breakaway devices are available from radiocollar manufacturers (e.g., latex tubing from Telonics, Inc.; Strathearn et al.'s [1984] design from Lotek Engineering, Inc.), but are more expensive (>US$40 added to the price of the standard radiocollar). These manufacturers informed us (S. Tomkiewicz, Telonics, Inc., Mesa, Ariz., pers. commun., 1994; J. Vanden Elzen, Lotek Engineering Inc., Newmarket, Ont., Can., pers. commun., 1994) that about 15% of the collars purchased by bear biologists over the past few years have been configured with breakaway devices, despite what appears to be a fairly high rate of premature break-off for these designs (Table 3). Biologists that use these commercially-made breakaway devices may prefer collars that might break too early to ones that could stay on too long.

Leather appears to be the longest-lasting breakaway linkage, and thus might be considered the least safe for bears. In Maine, 23 of 672 bears (3%) experienced neck injury due to large weight gains in autumn; neck injuries were more frequent (5%) during years with abundant fall food than when food was less abundant (2% neck injuries). However, we found that none of the bears in Maine or Minnesota with leather-linked collars that stayed on longer than desired (i.e., >2 years) experienced neck injury, even though 2 links in our study, 1 in Maine and 1 in Minnesota, had not broken after 4 years. Links lasting extraordinarily long periods have been observed in other studies as well: a collar made completely of leather stayed on a bear for 6 years with very little deterioration (P.McConnell, pers. commun., 1994), and firehose links remained intact on 2 bears for 6 years (B. McLellan, pers. commun., 1994; B. Noble, U.S. Fish and Wildl. Serv., Leavenworth, Wash., pers. commun., 1994). We observed, though, as have others (Seibert and Wooding 1994), that some of the leather links that stayed on longer than expected could be torn by hand. We also found that some links broke as hunters grabbed the collar to drag a dead bear out of the woods or we grabbed the collar to pull an immobilized bear from its den, indicating that the leather was weakened and likely would have broken if neck growth exerted sufficient pressure on it; conversely, a link might not break, even after a few years of weathering, if the collar did not get tight. The fact that premature break-offs (for various types of links) tended to occur more frequently on males than females (Hellgren et al. 1988, Seibert and Wooding 1994, our study) and mainly during late summer when bears were putting on weight suggests that breakage often may be caused by rapid neck growth. This hypothesis, that neck growth may hasten breakage of links, was corroborated during the winter of 1996–97 in Minnesota, where following a record-abundant food year in which many bears exhibited extraordinarily high weight gains, 6 collars with leather links (not included on Table 1) broke off at or near den sites. Thus, a simple comparison of the proportion of premature break-offs and links that seemingly lasted too long (Tables 1 and 3) may give a false impression of reliability; many of these links may have functioned as they were intended, breaking if and only if the collar got too tight.

We cannot, from the data compiled here, recommend a particular breakaway design. Our objective was only to synthesize the available information, enabling biologists to make the choice themselves. Data from a range of studies are available for only a few types of breakaways (Table 3), but many other types have been tested on bears (Table 2) and some types, used on other species, could be adapted for bears (e.g., Jackson et al. 1985, Holzenbein 1992). Radio-triggered anesthetic-dart capsules (Van Citters et al. 1967) or collars (Mech et al. 1984, Mech and Gese 1992) provide an alternate means of enabling routine collar adjustment, but their high cost precludes their use solely to ensure proper collar fit; furthermore, breakaway links would still seem advisable in the event of unsuccessful triggering. Options also exist for implanting transmitters (J. Goodrich, Univ. Wyoming, Laramie, pers. commun., 1994), gluing them on the back, or attaching them to an ear, instead of around the neck (Servheen et al. 1981). Studies attempting ear-mounted transmitters on bears have reported high rates of radio failure and premature drop-off (Bjarvall and Sandegren 1987), although new modifications to the attachment mechanism may improve retention (S. Miller, Alas. Dep. Fish and Game, Anchorage, pers. commun., 1994; H. Jolicoeur, Quebec Wildl. Dep., Quebec City, Can., pers. commun., 1994 and 1996). We feel that any of these attachments, chosen to reduce the chance of injury to radiotagged animals, would be preferable to relying strictly upon recapture and adjustment of fixed-size, permanent collars.

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