Evaluation of Longevity and Wear of Colored Plastic Leg-bands on Sandhill Cranes in Wisconsin

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ABSTRACT

We investigated durability and retention of colored plastic leg bands deployed on Sandhill Cranes (Grus canadensis) *by the International Crane Foundation from 1991 to present. Overall, band retention was high (>90%) across 20 years of observation. A logistic regression model showed that four variables (band height, sex of bird, year of band deployment, and radio presence/absence) significantly affected long-term band retention. Short bands (2.5 cm) were 4.5 times more likely to become detached than tall bands (7.5 cm). Males were 2.3 times more likely to lose short bands as females, although females showed more wear on recovered tall bands over time. Low quality plastic likely increased band loss in 1996 - 1997. The largest factor affecting short band retention was the attachment of a radio transmitter which increased the weight and wear on plastic thickness. Short bands with radios attached were 4.0 times more likely to be lost as short bands without radios. Attaching a radio decreased short band average and maximum life span by five years. Overall, our colored leg band construction showed long-term retention on Sandhill Cranes. Two possibilities exist to reduce band loss due to transmitter weight: 1) mount leg-band transmitters on tall bands to test whether this will maintain short-band longevity without sacrificing tall band longevity, or 2) use backpack harness mounted transmitters instead of leg-mounted transmitters. These recommendations can significantly increase band retention, thereby reducing band loss in a marked population of a long-lived avian species.*

INTRODUCTION

Many different types of markers have been deployed on wild birds to identify individuals in the field (see review in Marion and Shamis 1977). When a bird is captured and banded in the United States and Canada, each bird receives (at minimum) an aluminum U.S. Geological Survey (USGS) or Canadian Wildlife Service (CWS) band with an engraved nine-digit number. If this is the sole marker deployed, the bird needs to be recaptured to identify the individual. These engraved digits are not easily visible with binoculars or spotting scope (Bailey et al. 1987). Each capture event increases stress levels in a bird (Romero and Remage-Healey 2000), so applying auxiliary markers allows frequent identification of individuals and data collection without the added stress of recapture (Bird Banding Lab web page: http://www.pwrc.usgs.gov/bbl/index.cfm). For most species, colored plastic leg bands, which may or may not include a unique identification code, are the most reliable and widely used marker for long-term identification in the field (Calvo and Furness 1992). In general, colored plastic leg bands are widely used across most avian species, although application of leg bands can affect behavior and reproduction in some avian species (Metz and Weatherhead 1991, Zann 1994).

Loss of colored plastic leg bands could cause incorrect identification of an individual bird

(Nelson et al. 1980, Spear 1980). Many studies on wildlife populations require a way to identify individuals to determine individual survival (Frankhauser 1967, Nelson et al. 1980, White 1983), home range or territory size (Delaney et al. 1995, Porneluzi and Faaborg 1999), reproductive success (Wikelski et al. 2000), and dispersal (Threlfall 1978, Wiens et al. 2006). Additionally, mark-recapture analyses (Jolly 1965, Seber 1965) require accurate identification of individuals to approximate population size (Anderson 1980, Gazey and Staney 1986), population change over time (Pradel 1996) and immigration/emigration between populations (Whitehead 1990). Therefore, reduced confidence in identification could negatively affect the ability to model growth and sustainability of avian populations.

Colored plastic and USGS/CWS aluminum leg bands have been applied to Sandhill Cranes (*Grus canadensis*) in many populations over the past 50 years (Williams and Phillips 1972, Drewien and Bizeau 1974, Boise 1979, Tacha 1979, Nesbitt 1984, Hoffman 1985). Of these studies, however, only Hoffman (1985) provides a thorough methodology regarding band construction and longevity up to 10 years after deployment. To assist other researchers considering banding cranes, we provide a detailed methodology we have used for band construction and deployment on Sandhill Cranes. In 1991, the International Crane Foundation (ICF) began banding Sandhill Cranes annually in south-central Wisconsin (Hayes et al. 2003) to investigate habitat selection (Su 2003), survival and fecundity of breeding adults and pair bond duration within territorial pairs, as well as dispersal of chicks from natal areas. Additionally, 40-g radio transmitters were attached to colored plastic leg bands on some birds to assist in monitoring movements, calculate territory and home range size, and study habitat use by breeding and non-breeding birds (Su 2003).

Our first objective was to determine the longevity of colored plastic leg bands deployed on Sandhill Cranes by the ICF. We recorded the number of years that colored plastic leg bands remained on an individual bird and determined whether specific variables (e.g., sex of the bird, year of deployment, radio deployment on the band, or band height) would affect long-term band retention. We developed four main hypotheses. First, we hypothesized there will be no difference in band loss between males and females as there should be no differences between the sexes in behavior towards these bands or in behaviors that may affect band wear, such as incubation. Second, we hypothesized that band age would increase the probability of band loss. Third, we hypothesized that the added weight of radio transmitters would cause bands with these attached to fall off earlier than bands where no transmitter was attached. Lastly, we hypothesized that short bands (2.5 cm) would fall off at an earlier age than tall bands (7.5 cm) because the added height would aid in longevity.

Our second goal was to evaluate wear patterns of colored plastic leg bands removed from recaptured live birds or collected from dead birds. We recorded the thickness of the plastic for different aged bands and evaluated the effect of band age, band color, and sex of the bird on plastic thickness. We hypothesized that plastic thickness would decrease with age, but there would be no difference in wear based on band color or the sex of the wearer.

METHODS

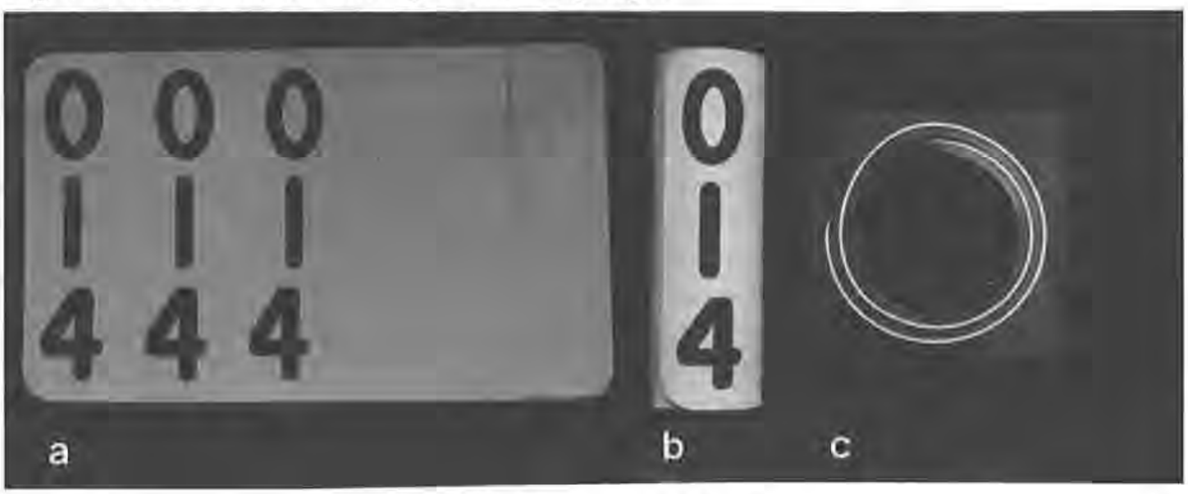
Study Area. – Sandhill Cranes were banded near Briggsville, WI (43° 36' N, 89° 36' W). This is an agricultural landscape intermixed with small woodlots or forest patches, grasslands, flow-through wetlands, and dispersed human residences (see Su 2003). This area has a high density of Sandhill Crane breeding pairs (Su et al. 2004) and flocks of non-breeding cranes, which consist of sexually immature birds, pairs that have not yet obtained a breeding territory, and birds that lost territorial status (Hayes and Barzen 2006).

Colored leg band construction for Sandhill Cranes. – We deployed a redundant banding scheme which allowed identification of the bird by a wide audience with varied training in re-sighting colored leg bands. Colored plastic leg bands for Sandhill Cranes were constructed from 0.16 cm thick, exterior-rated (UV-resistant) plastic sheets (Gravoplỹ 2-plex, Gravotech, Inc., Duluth, GA) that were bi-layered with two contrasting colors. From 1991 to 1999 we used matte finish and from 2000 to 2010 we used textured finish. Plastic sheets were cut into two different-sized pieces (tall and short) that were shaped into bands. Tall bands (deployed 1991 - 2010) measured 7.6 cm by 11.4 cm (Fig. 1-a). Tall bands were engraved with a three-digit number using a rotary bench engraver. We engraved a matrix of nine digits (three by three; Fig. 1-a). The left hand column had an approximately 0.64 cm margin from the left, top, and bottom sides of the plastic band to allow for wrapping (see below), and there were approximately 0.64 cm between the digits in the same column and 1.91 cm between digits in the same row. After wrapping, the band number "001" could be read vertically on three sides of the band (Fig. 1-b) to allow for maximum probability of reading the number accurately in the field. Three different colors of tall band were deployed during this study. From 1990 - 1997, green bands with white numbers were deployed; in 1998 - 1999, blue bands with white numbers were deployed; and from 1999-2010, yellow bands with black numbers were deployed.

In addition to tall bands, short bands (deployed from 1994 to 2010) were produced by cutting 2.5 cm by 11.4 cm or 13.3 cm strips. Using five colors (green, red, yellow, and white [1994 – 2010], blue [1997 – 2010]) for short bands and the USGS band, we generated 170 unique color combinations for deployment on one leg (with the tall band on the opposite leg). Thirty-five combinations consisted of two short plastic leg bands (or one short band and the USGS band) and 135 combinations consisted of three short plastic leg bands (or two short bands of the same color and the USGS band). We doubled that number of combinations by switching the legs that received the tall and short bands for a total of 340 color combinations before we needed to switch the color of the tall band. While adding orange plastic short bands in 1997 increased our color combinations to 552, orange was removed after this year because there was difficulty in distinguishing these from red plastic short bands, especially at long distances.

Each cut plastic piece was manually sanded with a metal file to smooth the edges and corners to reduce the chance of abrasion on the leg. After cutting and sanding both short and tall bands and engraving tall bands, all bands were shaped to fit around the bird's leg. Each band was heated in an electric oven set at 121°C until the plastic was soft and malleable. Once heated, the plastic was wrapped clockwise around a 1.91 cm diameter dowel rod, starting with the right-hand (un-

Fig. 1. Images of engraved plastic leg bands before deployment on Sandhill Cranes. Photos courtesy of Hillary Thompson, International Crane Foundation. a. Pre-wrapped tall band showing layout of engraved numbers. b. Wrapped tall band from the side view. c. Wrapped tall band from the top view. Note amount of overlap that occurs between leading and trailing edges.



engraved) portion of the band so that the left-hand (engraved) portion was not obscured when wrapped. This allowed between 2/3 to 3/4 overlap of the plastic layers for tall bands (Fig. 1-c) and 4/5 overlap for short bands.

Sandhill Crane capture. – Sandhill Cranes were captured using two different techniques. Flightless chicks (age 35 - 70 days) were chased on foot until they could be apprehended by hand (Hoffman 1985). Volant adults and family groups (with one or two fledged chicks) were conditioned to arrive at sites baited with whole kernel corn and then sedated with alpha-chloralose (Bishop 1991, Hayes et al. 2003) under the auspices of U.S. Fish and Wildlife Services (U.S. Department of Agriculture, Waupun, WI).

Once captured, Sandhill Cranes were banded with an aluminum butt-end (1990 - 1991) or rivet (1993 - present) USGS band (engraved with a unique nine-digit number) placed above the toes or above the tarsal joint for long-term identification. In addition to the USGS band, each bird received an engraved tall plastic leg band placed above the tarsal joint. All birds captured 1994 - 2010 received a unique combination of two or three short bands placed above the tarsal joint on the opposite leg (see examples at www.bandedcranes.org). Tall bands were more difficult to deploy than short bands due to increased height of the band. To minimize stress fractures on the plastic during deployment, bands were warmed for 5 to 10 min using body heat of the bander. After attachment to the bird's leg, both tall and short bands were visually scrutinized to detect any stress fractures that may have occurred during deployment. Any bands that were cracked or broken were removed from the bird's leg using tin snips and a new band was deployed. PVC primer and glue were used to seal the overlapping plastic of the bands, with a goal of increasing longevity. Trained banders with at least one field season of band deployment on Sandhill Cranes applied the tall bands and the PVC primer and glue on tall and short bands. To assist in training of interns and visiting colleagues, a trained bander observed the deployment of bands and glue to minimize errors. Some cranes received 40-g leg-band mounted radio transmitters (Advanced Telemetry Services, Isanti, MN) that had a 12 to 24 month life span. The back of the transmitter had a concave shape that fit the curvature of two of our short bands (Melvin et al. 1983). We sent the transmitter manufacturer wrapped short bands that they cut and fused onto the concave portion of the transmitter to maximize glue adhesion when deployed. Before deployment, this concave area was swabbed with primer and glue, mounted on two short bands, and then held in place with sticky stretch gauze until the glue dried. The gauze was removed and the adhesion between the transmitter and short bands was visually scrutinized before release of the bird. Leg-mounted transmitters were regularly deployed from 1995 - 2003 with sporadic deployment through 2006.

Age (hatch-year chick or after-hatch-year adult) of each crane was determined by presence and extent of red skin on the bird's head (Lewis 1979). Typical morphological measurements (culmen, tarsus, wing chord, and weight) were collected from all birds. Sex was determined by morphological measurements (males are typically larger than females; Nesbitt et al. 1992), vocalization (males have a deeper pitch to their voice and a different posture during a unison call; Archibald 1976), or genetic analysis using a blood sample (Griffiths et al. 1998, Duan and Fuerst 2001).

Post-release observations of banded cranes. – Banded Sandhill Cranes were observed regularly from March through November each year. We analyzed data from birds banded from 1991 to 2010 and included observation data through 2011 to allow at least one year of wear on the most recent deployed bands. When a banded crane was observed in the field, binoculars or a spotting scope were used to record a re-sighting observation exactly as the observer read the bands. The re-sighting observation includes color and numbers for the tall band, colors and order for the short bands (from the feathered portion of the tarsus down to the hock joint), and location of the USGS band.

Statistical Analyses. – A logistic regression model (Sokal and Rohlf 2001) was used to determine which variables (band height, color, length of time deployed on a bird, year the band was deployed on the bird, whether the band was equipped with a radio or not, and the sex of the bird on which the band was deployed) best predicted whether the band fell off (set as response variable of "1") or if it was retained on the bird until the ultimate observation (set as response variable "0"). Bands collected from recaptured or dead birds were set as "0". We used stepwise removal of non-significant variables ($p < 0.05$) from the full model. We removed the variable with the highest p-value and then re-ran the model and repeated this procedure until only significant variables remained. Best model selection was verified by choosing the lowest AIC score (Burnham and Anderson 2010). Odds ratios (Sokal and Rohlf 2001) were calculated for each significant variable remaining in the model.

Previously deployed tall bands that were removed from recaptured living birds or recovered from the carcasses of dead birds were used to evaluate band wear. The age of the bands varied from less than two months to 18 years. Thickness of the plastic, to the nearest 0.01 mm, of each re-collected band was measured using calipers at four locations, approximately 90° apart, around the circumference of the band; these were used to calculate average thickness around the top and bottom of each tall band. The thinnest part of the top and bottom of each band was determined by visually searching the edge around the circumference and measuring the thickness until the smallest measurement on the circumference of the band was found. We used linear regression (Sokal and Rohlf 2001) to determine if the thickness of the plastic on the top and bottom of each band was related to the age of the band, the color of the tall band, or the sex of the bird on which it was deployed. Statistical comparisons were calculated in R (R Foundation for Statistical Computing, Vienna, Austria) and graphs were constructed in Microsoft Excel. Average values ± SE are reported in "Results".

RESULTS

Band deployment and loss. – From 1991 to 2010, 326 tall bands and 794 short bands were deployed on 318 individual Sandhill Cranes (including recaptures) that were observed at least once after the year of capture. Additionally, 58 of these 318 birds (18%; 25 males, 33 females) received 60 leg-mounted transmitters from 1995 to 2010 (two birds each received two different transmitters after battery failure of the initial transmitter).

Band retention was high for both USGS and plastic bands. Only one bird (originally captured in 1991) lost its USGS butt-end band (one of 318 USGS bands [both butt-end and rivet] or one of 12 butt-end USGS bands). This bird was recaptured in 2013 and both its tall band was replaced and new rivet USGS band was deployed. Loss of a rivet USGS band has not been documented in the ICF program, although wear has occurred around the bottom of the band and made some engraved numbers difficult to read (Fig. 2). Plastic tall bands (98.8%, $n = 326$) were retained more often than plastic short bands (93.1%, $n = 794$; Fisher's Exact Test = 13.9, df = 1, $p < 0.001$). Tall bands fell off at an average age of 12.0 ± 2.0 yr ($n = 4$ bands), while short bands fell off at an average age of 7.8 ± 0.5 yr ($n = 55$ bands). The average age when short bands fell off did not differ between males (8.0 ± 0.7 yr, $n = 35$ bands on 20 males) and females (7.5 ± 0.8 yr, $n = 20$ bands on 15 females; Mann-Whitney $U = 361.0$, $p = 0.85$). There was no significant difference in probability of loss for short bands placed as the top band (7.9%, $n = 290$), middle band (4.0%, $n = 223$), or bottom band (8.2%, $n = 281$; Fisher's exact test = 4.03, df = 2, $p = 0.12$).

Factors affecting band loss. – Results of the logistic regression analysis suggested four variables (sex of the bird, presence of a radio, band height, and year of band deployment) significantly affected band retention (Table 1). Although the model with the lowest AIC score included color, this variable was not significant and was removed from the final model. Males lost bands 2.3 more times than females. Short bands were 6.0 times more likely to become detached than tall bands. However, short bands with radios attached were 4.0 times more likely to fall off than short bands without radios attached. When we removed short bands that had radios attached, short bands were still 4.5 times more likely to fall off than tall bands. Instead of calculating odds ratios for each year-by-year comparison, we analyzed overall trends of band loss across years. With short bands, older bands were more likely to fall off than younger bands (Fig. 3), but this relationship was not observed for tall bands (note: only four tall bands have fallen off during this 20-year study).

Table 1. Results of the logistic regression models tested to determine which variables affect band loss in Sandhill Cranes.

Lost ~ Band Year + Sex + Color + Height + Radio

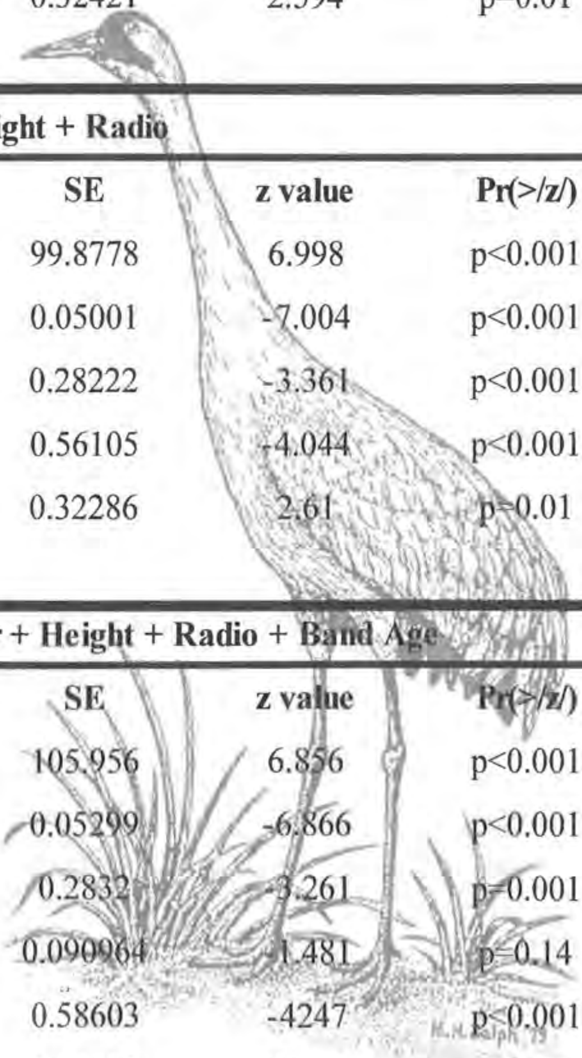
Coefficients:	Estimate	SE	z value	Pr(>/z/)	AIC: 343.2
(Intercept)	721.366	103.966	6.938	p<0.001	
Band Year	-0.36131	0.05203	-6.944	p<0.001	
Sex	-0.91819	0.28253	-3.25	p=0.001	
Color	-0.13414	0.09094	-1.476	p=0.14	
Height	-2.48784	0.58603	-4.245	p<0.001	
Radio	0.84095	0.32421	2.594	p=0.01	

Lost ~ Band + Year + Sex + Height + Radio

Coefficients:	Estimate	SE	z value	Pr(>/z/)	AIC: 343.4
(Intercept)	698.896	99.8778	6.998	p<0.001	
Band Year	-0.35029	0.05001	-7.004	p<0.001	
Sex	-0.94847	0.28222	-3.361	p<0.001	
Height	-2.269	0.56105	-4.044	p<0.001	
Radio	0.84263	0.32286	2.61	p=0.01	

Lost ~ Band Year + Sex + Color + Height + Radio + Band Age

Coefficients:	Estimate	SE	z value	Pr(>/z/)	AIC:345.1
(Intercept)	726.413	105.956	6.856	p<0.001	
Band Year	-0.3638	0.05299	-6.866	p<0.001	
Sex	-0.92346	0.2832	-3.261	p=0.001	
Color	-0.134722	0.090964	-1.481	p=0.14	
Height	-2.48863	0.58603	-4247	p<0.001	
Radio	0.81377	0.34452	2.362	p=0.02	
Band Age	-0.00851	0.03671	-0.232	p=0.82	



Background Whooping Crane

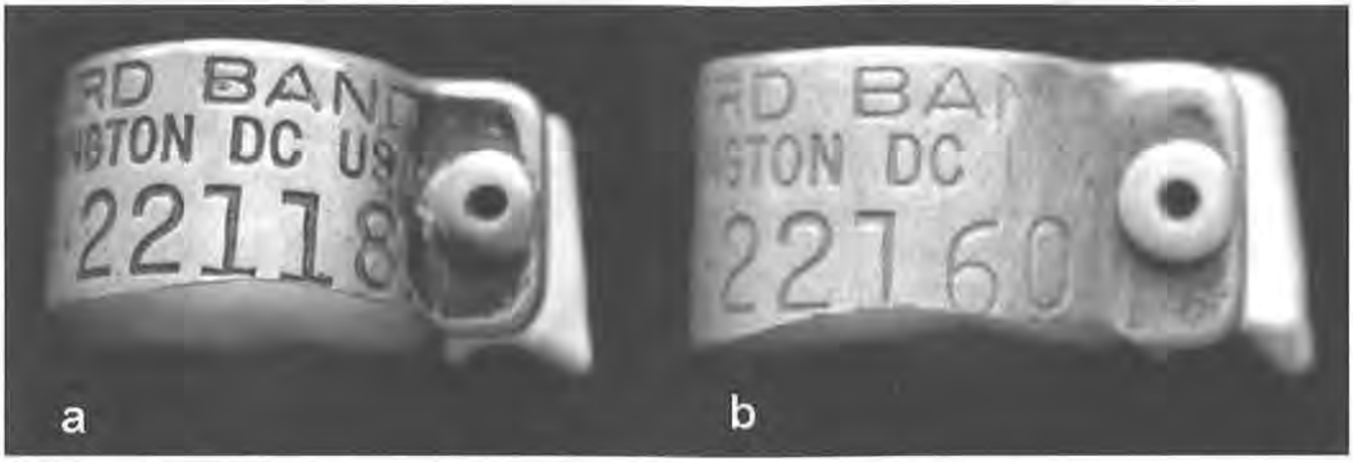


Fig. 2. Band wear of two aluminum USGS bands deployed on Sandhill Cranes. Photos courtesy of Hillary Thompson, International Crane Foundation. a. [629]-22118] was deployed on a male from 1996-2005. b. [629]-22160 was deployed on a female from 1997 - 2009.

The highest proportion of short bands lost was not in 1994 (the first year they were deployed), but rather two years later in 1996. Radio presence likely triggered some of the older short bands to fall off; however, band loss did not increase with number of radios deployed in a given year (Fig. 3).

Of 13 birds (10 male, 3 female) that lost short bands with radio transmitters attached, eight (62%; 5 male, 3 female) lost all of their deployed short bands. Comparatively, of 23 birds (10 male, 13 female) that lost short bands but did not have radio transmitters attached, five (20%; 4 male, 1 female) lost all of their

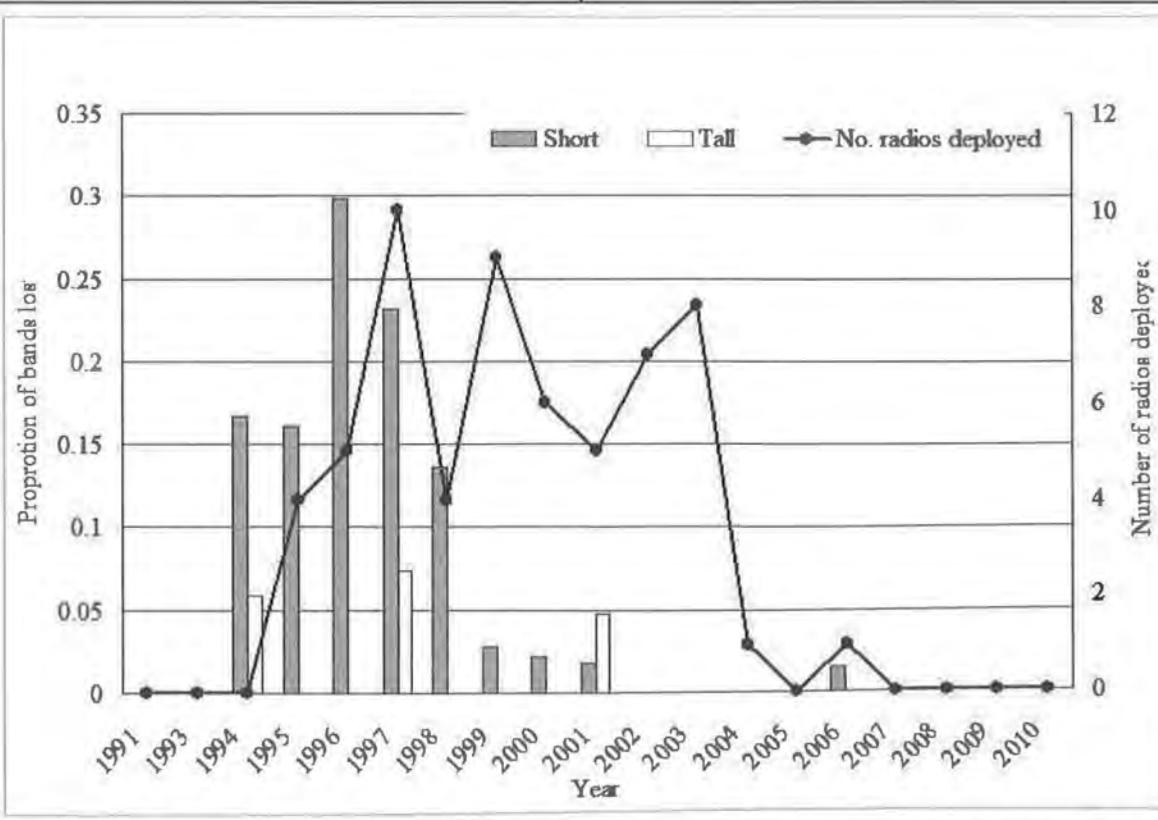


Fig. 3. Proportion of colored plastic leg bands that were deployed in a given year that eventually fell off and number of leg-band mounted radio transmitters deployed in that same year.

deployed short bands. For short bands without a radio attached, probability of retention decreased linearly with band age after three years (Fig. 4). The average age when a short band without a radio fell off was 9.5 ± 0.6 yr (range = 4 - 15 yr). At the time of this report, seven short bands have been retained on birds for 16 yr and one short band was retained on a bird for 17 yr, at which time the bird was recaptured and the short band was replaced. For short bands with radios attached, lifespan also decreased after 3 yr, but at a much steeper rate with a curve that is more asymptotic (Fig. 4). The average duration after which a short band with radio attached fell off was 4.7 ± 0.4 yr (range = 4 -10 yr). However, short bands with radios attached have been retained beyond 10 yr. Two short bands with radios attached were deployed for at least 11 yr, six bands for at least 12 yr, four bands for at least 13 yr, and one band for 15 yr, after which the bird disappeared.

Natural wear on plastic thickness of tall bands. – We had a collection of tall bands from known individuals and we measured these tall bands, rather than a fewer number of short bands from unknown individuals or locations in the color combination, to understand more about patterns of wear on plastic leg bands. For re-collected tall bands, there was no significant effect of sex or age on average plastic thickness on the top and bottom of tall bands (Table 2). The degree of thinning of the top of the band was significantly associated ($F_{2,29} = 35.0$, $p < 0.001$, $R^2 = 0.73$) with the number of years deployed (slope = -0.004, $p < 0.001$) and sex of the bird (slope = 0.01, $p = 0.05$; Fig. 5); there was no significant association between color and tall band wear. The thinnest portion of the top of bands on females was significantly smaller than the thinnest top portion of bands on males (Mann-Whitney $U = 185.5$, $p = 0.03$; Table 2). The thinnest portion of

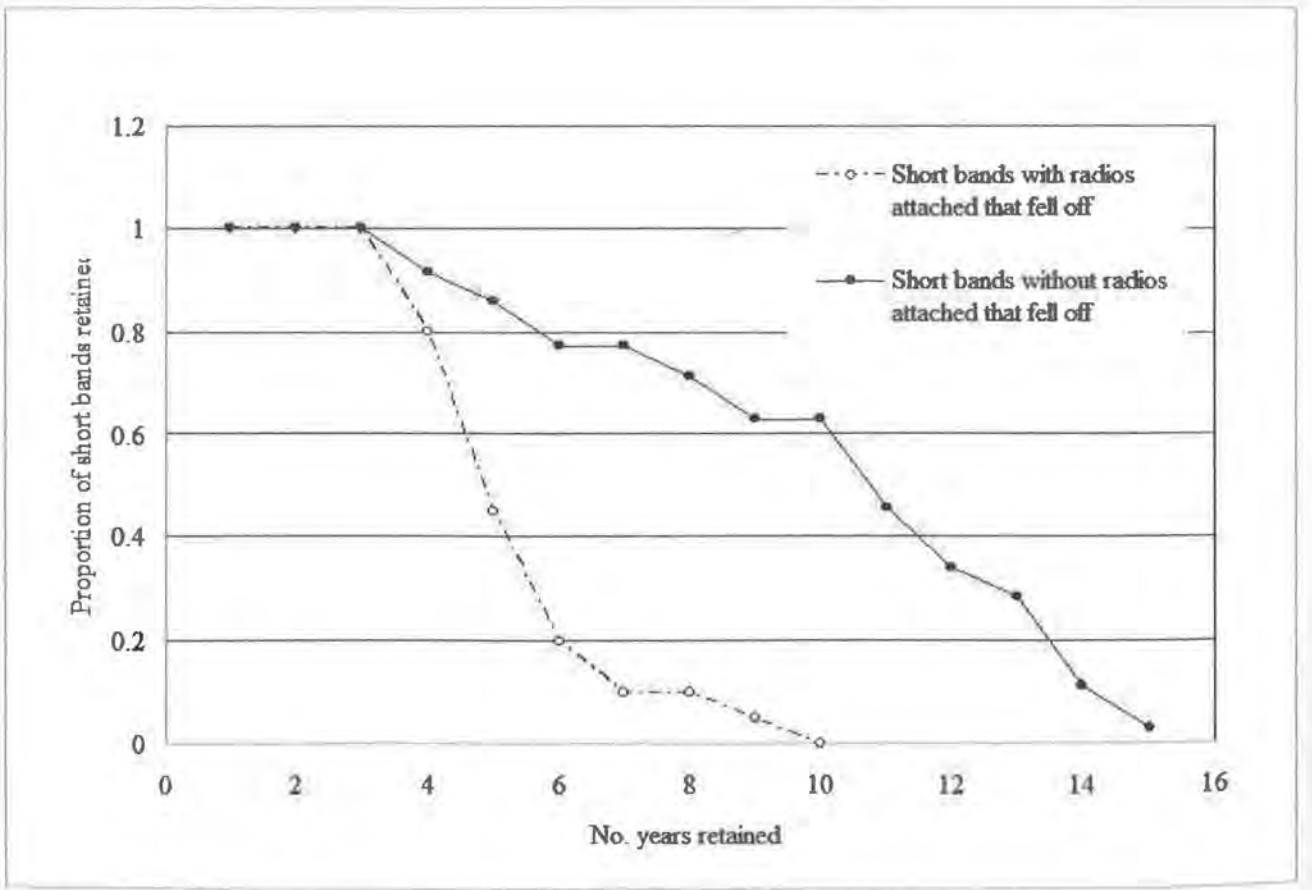


Fig. 4. Proportion of short bands retained and the effect of leg-band mounted radio transmitter attachment on band longevity.

the bottom of a band also decreased significantly over time ($F_{1,29} = 73.0$, $p < 0.001$, $R^2 = 0.72$, slope = -0.006, $p < 0.001$), but there was no difference between the sexes.

DISCUSSION

Overall, band loss occurred at a low frequency for both tall (less than 2%) and short bands (less than 7%) over the 20 yr of observation, suggesting high durability for the band design used in this study. These durability

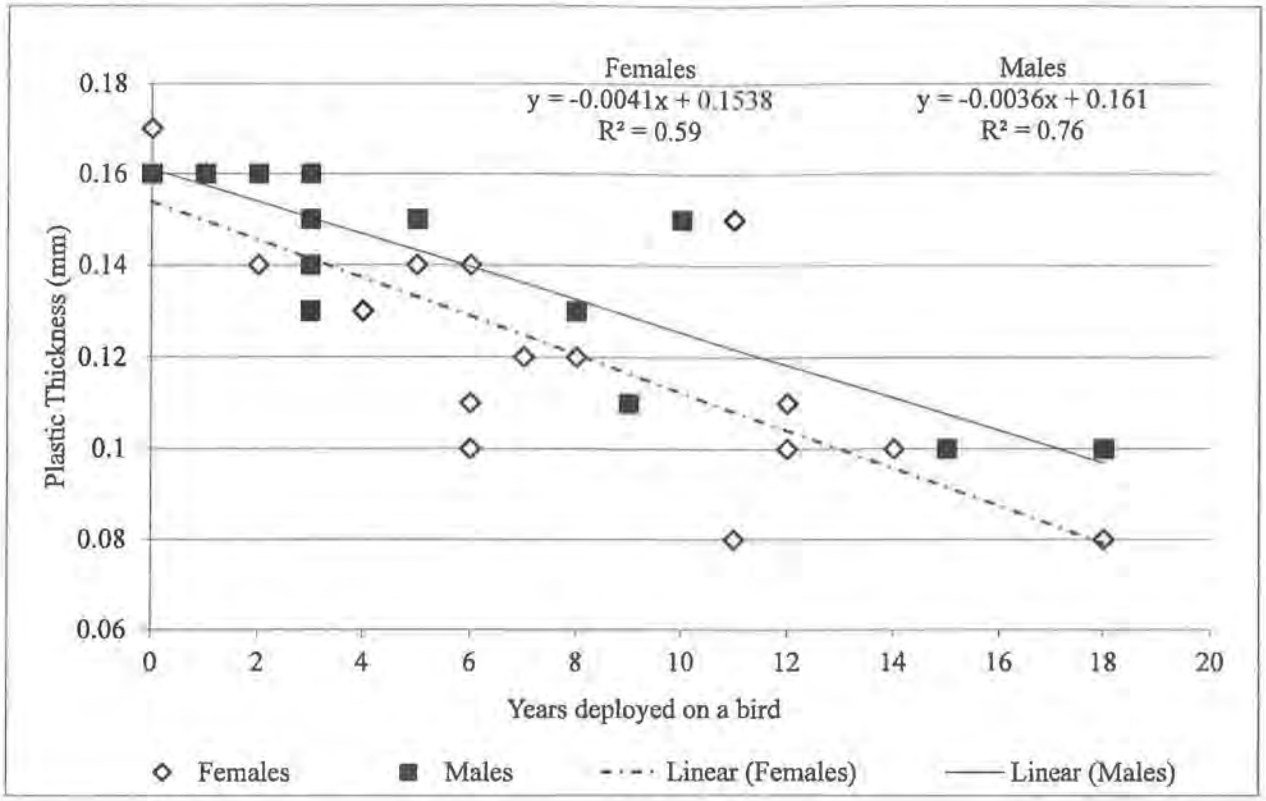


Fig. 5. Relationship between number of years deployed and the thinnest worn portion of the top of the tall band place on male and female Sandhill Cranes.

Table 2. Thickness of plastic (cm) of re-collected tall bands from Sandhill Cranes 1991-2010.

		Top Portion of Band		Bottom Portion of Band	
		Thinnest	Average	Thinnest	Average
Females	Average	0.12	0.16	0.11	0.16
	SE	0.007	0.003	0.010	0.003
Males	Average	0.14	0.17	0.13	0.17
	SE	0.006	0.003	0.008	0.003
Overall	Average	0.13	0.16	0.12	0.17
	SE	0.005	0.002	0.007	0.002

frequencies exceed estimates observed for Sandhill Cranes by Hoffman (1985) which showed a 10-yr maximum of re-sighting a color-banded bird. High band resilience increases the probability of the band remaining on the bird throughout its long lifespan which can exceed 20 or 30 yr. High band retention leads to higher confidence in correct identification of an individual, which will provide better long-term estimates of population size, survival, and fecundity.

Because we use a redundant system, does band loss affect our ability to identify individual Sandhill Cranes in the field? If a crane loses a USGS band, this bird can still be correctly identified in the field based on its colored plastic leg bands. For lifelong identification, however, we would still attempt to recapture this bird to apply a new USGS band in case all of the plastic leg bands fell off.

If a bird loses a tall plastic leg band, confidence in identification would rely on the short band color combination. This confidence would decrease in proportion to the total number of tall band colors deployed. In this study, the highest overlap in short color combinations used was with green and yellow tall bands. Considering we have only lost four tall bands throughout this 20-yr study, loss of tall bands was not a major source of misidentification as long as the short band color combination was retained on the bird. Observations of tall bands in the field and recovered from recaptured birds showed large sections of plastic missing which can include portions of the engraved number. Missing plastic would affect our ability to read the engraved number and potentially reduce confidence in identification; however, the number is often still read correctly because it is engraved on three sides of the tall band. These missing sections of plastic could increase abrasion on a crane's leg; however, we have not observed obvious distress on the leg scales of recaptured birds with degraded bands.

The largest potential source of error in individual identification was through the loss of short bands. There were 35 birds that lost bands during 20 yr of observation. Of these 35 birds, 20 birds (57.1%) lost one of their short bands, 11 (31.4%) lost two short bands and four (11.4%) lost three short bands. For birds with three short bands in their combination who lost one of those bands, that combination would mimic a bird with only two short bands deployed and the only way to differentiate between these birds would be through observation and recording of the engraved number on the tall band.

Why is the loss of short bands important for correct identification of banded Sandhill Cranes? From 1993 to 2011, trained ICF staff made 25,752 re-sightings of color-banded birds where the tall band number was read or the color of the tall band and the color combination of short bands was recorded. Of these re-sightings, 25,303 (98.3%) were considered "high" confidence, meaning the observer did not doubt that their identification was correct and this was verified by matching observer identification to the list of possible combinations of short bands. Of the total 25,752 re-sightings, 12,436 (48.3%) included the tall band number being read of which 11,861 (46.1%) had the tall band number read correctly. So, 52.7% of our "high" confidence re-sightings relied solely on correct observation of the short band color combination (in addition to the color of the tall band) to correctly identify an individual Sandhill Crane.

Does confidence of sightings not made by trained International Crane Foundation staff differ? From 1991 to 2011, we received 482 sightings from birders, farmers, or other interested parties that observed banded Sandhill Cranes both in Wisconsin and other states east of the Mississippi River. Of these 482 sightings, 467 (96.9%) were high confidence, suggesting that we were able to correctly identify the banded individual from the provided information. Of these 482 sightings, observers recorded the tall band number in 387 (80.3%) sightings, of which 363 (77.7%) recorded the number correctly. Therefore, approximately 20% of these high confidence sightings relied on the combination of short bands to correctly identify the bird. Interestingly, from 1990 to 2008, only 47.0% of 117 sightings had the tall band number read correctly whereas this improved to 84.4% of 365 sightings from 2009 to 2011. Additionally, digital photographs were included with 32 of the observations from 2009 to 2011, which assisted in correctly identifying a banded Sandhill Crane.

Factors affecting band loss. – While male Sandhill Cranes had higher occurrence of short band loss than females, tall bands recovered from females showed more wear (reflected as increased plastic thinning) than tall bands deployed on males. The reason for these results is unknown; however, they could suggest behavioral or anatomical differences between males and females. Male Canada Geese (*Branta canadensis*) lost plastic neck bands more often than females, and Coluccy et al. (2002) hypothesized that this could be a result of a higher rate of aggressive interaction between males. While Sandhill Cranes are highly territorial, aggressive contact is extremely rare and aggression is also not normally focused on a bird's legs (Tacha 1988). Female Red-billed Gulls (*Chroicocephalus scopulinus*) had higher aluminum band loss than males and Mills (1972) speculated this may be caused by more movement of the band on a female's legs (relatively thinner than a male's legs) and perhaps more time spent incubating in abrasive habitats. With Whooping Cranes (*Grus americana*), leg diameter was measured and it was determined that this measurement is above the hock joint and is larger for males than females (ICF, unpublished data) which could cause more movement of a leg band up and down the leg. With Sandhill Cranes, male and female incubation times and duration are equivalent (Nesbitt 1988) and the birds typically nest in "non-abrasive" freshwater wetland habitat (Meine and Archibald 1996).

While there was a year effect detected with short band longevity, supporting our hypothesis that older bands would fall off first, it was not necessarily an effect of band age. Short bands deployed in 1996 and 1997 had a higher probability of loss than bands used before and after this two-year period. This is likely due to a difference in the durability of the plastic used in these two years compared to other years. The small influence of color on the AIC scores of the two top models is likely influenced by the nine orange short bands deployed on birds in 1997. Of these nine orange short bands, three bands had radios attached and four bands fell off. Even after these nine bands were removed from analysis, the significant variables influencing band loss were year deployed, height, radio, and sex.

In this study, the variable having the largest effect on short band duration was deployment of a radio transmitter on the leg bands. The addition of a radio to one side of the short bands likely caused uneven weight distribution and disproportionate wear, resulting in shortening of the lifespan of the short bands compared to when no transmitter was attached. An added complication from uneven weight distribution may be increasing risk that the leg carrying the transmitter will collide with objects in the environment, such as power lines. Leg band mounted radio transmitters protrude approximately 2 cm from the exterior of the leg band and transmitters often hang down while in flight (Hayes, personal observation). Power line collisions are rare events for Sandhill Cranes (Ness 2011), so the collision of a radio transmitter with a power line is unlikely to be a major cause of band loss. However, of 44 documented interactions between power lines and Whooping Cranes living in Florida, 50% occurred with the leg carrying a radio transmitter and 39% of these caused the transmitter and bands to be separated from the leg (Miller et al. 2010, Folk et al. 2013). While power line collision often caused leg injury or mortality for Whooping Cranes in Florida (Miller et al. 2010), this was not always the case as some individuals that collided with power lines lost leg bands with radios attached, but survived and remained uninjured. This has not been an observed issue with Whooping Cranes in the introduced Eastern Migratory Population in Wisconsin (R. Urbanek, U. S. Fish and Wildlife Service, pers. comm.).

Tall bands had longer lifespans than short bands, supporting our hypothesis that added height would lead to greater long-term retention. This was true even when short bands with radio transmitters attached were removed from the analysis. One alternative to mitigate the effect of radio deployment on short band retention (and therefore improve radio transmitter retention) is to consider attaching them to the tall band. Whether radio transmitter attachment will also shorten the lifespan of tall bands is unknown, but is currently under investigation (J. Fox, University of Illinois at Urbana-Champaign, pers. comm). Radio transmitters deployed on Whooping Cranes in the introduced Eastern Migratory Population are deployed on a 7.6 cm baseplate which attaches to two 3.8 cm bands

(Urbanek 2010) and there has not been any observed transmitter or band loss in this population (R. Urbanek, U. S. Fish and Wildlife Service, pers. comm). In 2006, the ICF Sandhill Crane program began using backpack radio transmitters that are mounted on the back of the bird via a harness of Teflon ribbon (Nagendran et al. 1994). Moving to an 80-g backpack transmitter would reduce weight and strain on short bands. A benefit of the backpack units is an increase in radio lifespan from 12 - 18 mo (leg-band mounted) to 24 - 36 mo. A concern with backpack transmitters is that improper deployment of the harness can lead to abrasion on the wings and body of the bird that can be corrected with proper training and harness deployment (S. Hereford, U. S. Fish and Wildlife Service, pers. comm.).

While we had long-term band retention for both tall and short bands, we are curious if there are new opportunities that can be tested. The Fraunhofer Institute for Chemical Technology (Pfinztal, Germany) developed a new short band design for deployment on Eurasian Cranes (*G. grus*). Construction includes two halves of a band made from molded plastic with tongue and groove edges that snap together around a bird's leg. Beginning in 2009, these bands have been deployed on endangered Mississippi Sandhill Cranes (*G. c. pulla*; S. Hereford, U.S. Fish and Wildlife Service, pers. comm.). Preliminary results show the bands are remaining on the birds, but long-term evaluation is necessary to determine any drawbacks that may occur as a result of wear or incomplete closure of the two halves which could allow accumulation of debris or water causing wear over time.

An understanding of colored plastic leg band retention is necessary when conducting studies that depend on individual identification on long-lived avian species, such as Sandhill Cranes. Without durable bands, the probability of accurately identifying individuals throughout the lifespan of the study or bird decreases over time and can create error in modeling population size, individual survival, fecundity, and dispersal. To accurately monitor and model populations of long-lived birds, individual birds need to be regularly re-captured to replace plastic leg bands or band durability needs to be sufficient so that bands can potentially outlive their recipients. This study of colored leg bands on Sandhill Cranes confirmed this result with high band retention, plastic bands can be relied on in ecological studies of cranes, and we believe this can be increased with minor adjustments to colored leg band construction and radio transmitter deployment.

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