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COLOR-BAND IDENTIFICATION SYSTEM OF THE REINTRODUCED EASTERN MIGRATORY WHOOPING CRANE POPULATION

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Abstract: A reintroduction of whooping cranes (*Grus americana*) migrating between Wisconsin and the southeastern U.S. was initiated in 2001. A color-band system to uniquely identify individuals was necessary for monitoring and evaluation of that population. The system provided 336 individual unduplicated color combinations consisting of 3 base and 1 additional colors on plastic bands. The band combination on 1 leg carried a VHF transmitter and provided additional information on hatch year. Bands on the other leg were either small bands that were part of a permanent code or they were temporary and supported a remotely monitored (satellite or cellular) transmitter. Through 2017 the system has fully accommodated the identification and tracking requirements needed for the reintroduction and could continue to be used for a consistent method of identification in the future.

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Key words: banding, color-band, Eastern Migratory Population, *Grus americana*, identification system, transmitter, whooping crane.

Ability to identify individuals is important in many studies of wildlife and is critical for monitoring and management of reintroduced populations, especially of endangered species. Visual identification requires durable markers which have high visibility over long distances, across habitat types, and under all weather conditions. Because of their long legs, marking of cranes for identification is most effectively accomplished with colored plastic bands above the tibiotarsal joint (Hoffman 1985). These colored leg bands must also be capable of supporting transmitters needed for radiotracking. This paper describes the color-band identification system (hereafter banding system) used on the Eastern Migratory Population (EMP) of whooping cranes (*Grus americana*) that was reintroduced in Wisconsin and migrates to the southeastern U.S. This banding system has been in use since the reintroduction began in 2001 and continued through 2017. This paper is not intended as a comparison among crane marking approaches but rather as a reference providing a full description of the system currently used and its value for continuity over time for this reintroduction.

The banding system readily accommodates the needs of an identification program for reintroduced endangered whooping cranes. Those needs are more complex than required for banding of many natural bird populations. For example, the system could be used for banding wild sandhill cranes (*G. canadensis*) with no established identity before banding. However, that application could also just be a simple list of color-combination codes that are used in sequence as birds are captured for banding. The system used on the whooping crane EMP is especially versatile and suited to organized code assignment required to accommodate identification of birds by hatch year, especially annual cohorts of released captive-reared birds. This is accomplished by assigning a 2-color combination on the VHF (164-166 MHz) transmitter bands to specific hatch years. This greatly facilitates narrowing recognition of cranes to 1 or a few annual cohorts in the field even with only partial band readings, especially by the trackers who normally monitor the birds. The system also accommodates tracking requirements with 1 (and sometimes 2 different types) of radiotransmitters attached on the leg bands. The color combination can also be retained on individual cranes to maintain identification continuity following VHF radiotransmitter replacement.

MATERIALS

This banding system was similar to that originally developed for use in studies of sandhill cranes in Upper Michigan by the former Ohio Cooperative Fish and Wildlife Research Unit in the 1980s (McMillen 1988; McMillen et al. 1991; Urbanek et al. 1991; Urbanek and Bookhout 1992*a*, 1992*b*, 1994; Urbanek 2018). Construction of the original bands was based on

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earlier work by Hoffman (1985) with modifications for transmitter attachment by Melvin et al. (1983) and additional innovative improvements. The latter included use of 2 bands rather than a single band to carry the transmitter. A single 78-mm-high band is difficult to open without breaking or causing a stress fracture. Two shorter bands can be easily opened without damaging the bands; in addition they facilitate more color combinations.

There are 2 types of bands: 1) each small band was 25.4-mm high with up to 3 stacked on a leg, and 2) each long band was 39-mm high and a pair of these was used on which to attach a transmitter (Figs. 1 and 2). Each transmitter, whether VHF or remotely tracked (PTT [platform transmitting terminal, i.e., satellite], GSM [global system for mobile communication, i.e., cellular]) was attached by the manufacturer to a 75-mm-high, 26.3-mm inner diameter, semi-cylindrical base plate which exactly fit on the 2 long bands. All bands used in the project through 2017 were wrap-around type with an inner diameter of 22.9 mm and were custom-fabricated according to methods described by Urbanek (2010 [erratum: heating temperature was 175°C and not 125°C as reported in that publication]). Base plates were 0.76-mm-thick PVC (polyvinyl chloride) or ABS (acrylonitrile butadiene styrene) plastic with a haircell pattern on the outer (transmitter attachment) side. Color bands were 1.6-mm-thick ABS (Gravoply I; Gravograph [formerly New Hermes], Duluth, GA, USA) plastic with the exception of the small red bands, which beginning in 2004 were fabricated from a colorfast PVC (Darvic, no longer manufactured but alternative materials are being evaluated [Haggie Engraving, Crumpton, MD, USA]). That substitution was made because of significant fading of the red Gravoply. Base plates and VHF transmitters were painted with colorfast acrylic paint (Liquitex Artist Materials, Piscataway, NJ, USA) to match the color bands on which they were attached. For remote transmitters, only the base plates, not the transmitter itself, were painted. The water-based paint was very durable when applied to a slightly roughened surface. Because it was quick drying (dry to touch in

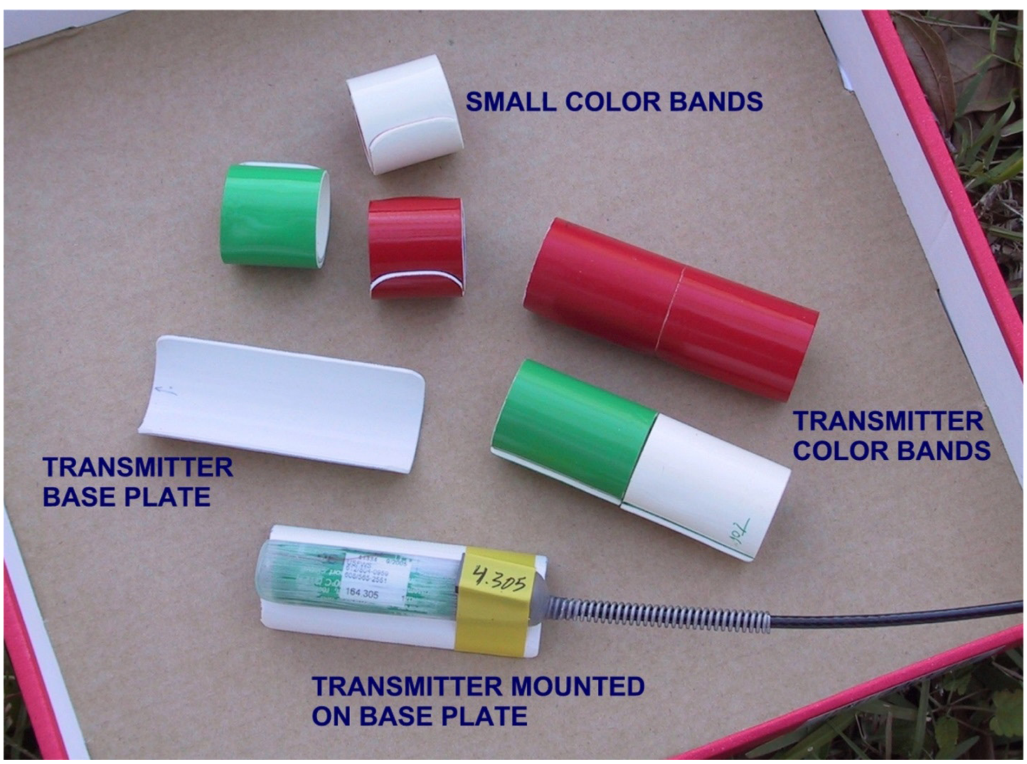

Figure 1. Components of color band identification system used on reintroduced whooping cranes in the Eastern Migratory Population. The transmitter manufacturer mounted the transmitter unit on the base plate. The bands were cemented closed and the transmitter (mounted on the base plate) was cemented onto long bands during banding in the field. Color bands and base plates were fabricated by the author.

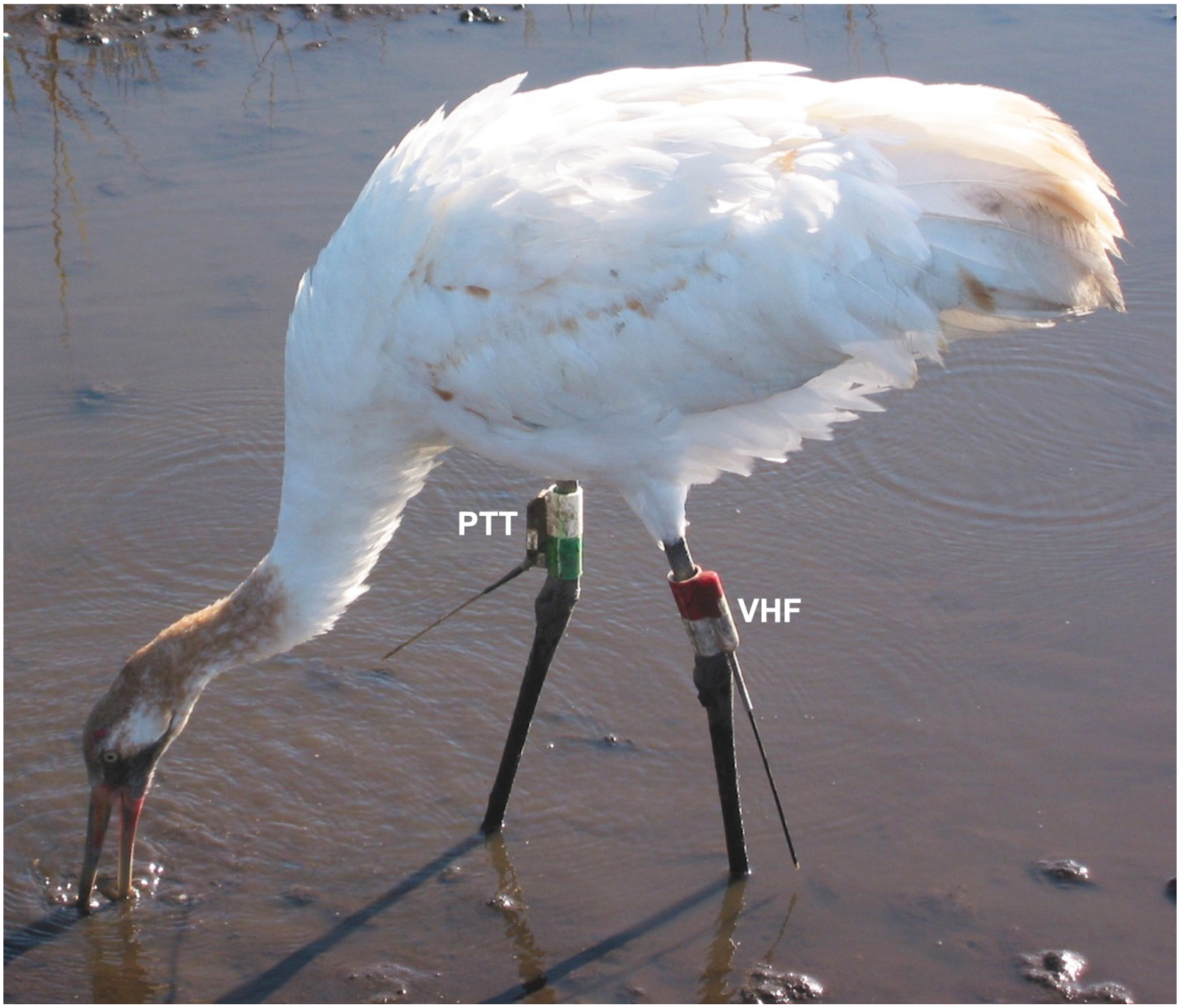

Figure 2. Whooping crane identified by color-coded long bands used for transmitter attachment in the reintroduced Eastern Migratory Population. The left leg has red over white (R/W) long bands with attached VHF transmitter. The right leg has white over green (W/G) long bands with attached remote transmitter, in this case a PTT (platform transmitting terminal). Photo by Sara Zimorski.

1 hr; completely cured by 48 hr), changing the color combination by repainting of transmitter-base plate units to meet changing banding plans for specific cranes in the field was easily accomplished. During banding, bands were cemented shut and base plates (containing transmitters) were affixed to bands with all purpose (plastic pipe) cement (Oatey, Cleveland, OH, USA). Bands were manually held shut for approximately 1 minute to allow cement to tack before proceeding further with the banding procedure.

Color bands were auxiliary markers applied under Federal Bird Banding Permit 23066 (2001-2017) and additional banding permits of project partners (2011-2017). In addition, an aluminum no. 9 lock-on band (USGS Bird Banding Laboratory [BBL]) cut down and reformed to 21.5 mm inner diameter was placed on the lower tarsometatarsus above the digits on the right leg of each crane. The band was modified because the BBL did not carry a lock-on band of optimal size for whooping cranes. This metal band was not part of the color-band identification system. The auxiliary marker authorization was coordinated among other banding programs to eliminate duplication of combinations and resulting misidentifications. For example, whooping cranes in the Louisiana reintroduction use the same system but with base codes of yellow, blue, and red and with black as an additional color (S. E. Zimorski, Louisiana Department of Wildlife and Fisheries, personal communication).

BAND ATTACHMENT AND LONGEVITY

The bands are wrap-around type (Urbanek 2010); therefore, except for the transmitter units themselves, they are completely streamlined with no flanges needed for attachment and without any other protrusions or recesses. Although studies are lacking, possible impairment of bird movement by protrusions (especially if present on both legs), which could increase susceptibility of birds to predation, increase possibility of icing, and interfere with leg tucking and thermoregulation of bird feet during freezing weather, was therefore avoided. Fusion into a single solid cylinder is the most structurally sound plastic band possible. To prevent possibility of cracking or breaking of the band under wet and freezing conditions, any spaces, however small, at contact points between transmitter bands or these bands and transmitter base plates were further sealed with cement. Total height of all bands on a leg did not exceed 78 mm. This height avoided rubbing on the feathered tibiotarsus and facilitated complete bending capability of the leg at the tarsal joint, even on the smallest females (R. P. Urbanek, personal observations).

Small bands (i.e., not transmitter bands) were cemented shut but were not cemented together on the fledged juveniles and adults banded in this population. In previous work on sandhill cranes (McMillen 1988; R. P. Urbanek, unpublished data), small bands were cemented together only on unfledged chicks to prevent sound caused by rattling of bands, and possible detection by predators, when the chick moved. No detected problems, such as entanglement in fishing line, have occurred as a result of not cementing the small bands into a single unit.

The longer time that bands last and remain colorfast, the longer birds can be accurately and efficiently monitored. These bands have a proven long life expectancy (8 or more years) under the climatic conditions on the eastern migration route. Sandhill cranes banded at Seney NWR with the same type of custom-made Gravoply bands currently being used on whooping cranes exhibited no significant loss at least 8 years after application (R. P. Urbanek, unpublished data). Sandhill cranes observed at Seney 15 years after banding and at least 1 banded in Ontario 24 years earlier still retained all of their bands. Because of such high band durability, the few band replacements needed during the whooping crane reintroduction could usually be made during the much more frequently needed transmitter replacements.

Recapture is highly disturbing to cranes, requires much effort, and becomes more difficult and time-consuming after the birds are more than a few years old. However, for this population the intensive research and monitoring have required periodic replacement of failed VHF transmitters, and few banding programs have gone to the length of this one to recapture birds for this purpose. This banding system of minimal colors (see below) and transmitters not attached to bands until banding occurred in the field readily accommodated transmitter replacement without changing the color-band identification code. This consistency in individual marking facilitated clarity and accuracy of the monitoring program. Through direct observation and resightings of 297 EMP whooping cranes initially banded in 2001-2017 followed by 122 transmitter replacements (latter data through May 2015; includes some multiple replacements per bird), no transmitter bands and less than 20 small bands have been lost. Although both types of band materials worked well, Darvic bands are harder and more brittle than Gravoply bands and had an approximately 3× higher loss rate (e.g., in complete color codes that had been assigned to cranes alive in the population in October 2017, 3/139 [2.16%] Gravoply and 4/66 [6.06%] Darvic small bands were missing; this 2.8× higher loss rate for Darvic was consistent with earlier estimated loss rates). Through 2010, VHF transmitters typically operated 3.5 years (mean) before battery failure, and nonfunctional transmitters were typically replaced within <1 year of failure. Later in the project, replacement time was greater and more variable. In addition to any missing bands, small bands which were chipped or cracked were also replaced when cranes were captured for transmitter replacement, but that number was low.

Disadvantages of these bands are minor and were further explained by Urbanek (2010). Finished wrap-around bands and transmitter base plates are not commercially available and must be custom-made by hand by an experienced band maker. Proper attachment of the bands to the bird and transmitters to the bands requires training, talent, and experience. Minimal banding time is 10 minutes because attachment to the bird requires assembly and cementing of separate components in the field. Because transmitters are painted to match the color code of the bands to which they will be attached, inventory must be large enough to include enough transmitters of appropriate colors for the current banding effort. However, because the bands are not attached to the transmitter until application in the field, any bands that are broken can simply be replaced during banding and the transmitter remains deployable. Alphanumeric codes, which are potentially unlimited, are not used because they are much more difficult to read than colors (Hoffman 1985; R. Urbanek, personal observations); therefore, the number of identification codes is limited by the number of unique color combinations. However, because the population is small and well-monitored and codes are recycled after mortalities, number of available codes has been adequate.

COLORS

Field identification of whooping cranes requires high readability of bands in the field, often in wetlands, through obscuring vegetation, or from long distances. Therefore, only colors and no alphanumeric codes are employed. To maintain systematic organization, minimize monitoring errors, simplify band fabrication, and facilitate future band and transmitter replacements, an effective and efficient banding system requires the minimum number of colors needed to cover the maximum number of individuals in the population. For a reintroduced population, this is initially 3 base colors. Colors should maximize brightness (to enhance visibility) and contrast (to enhance accuracy of reading). The 3 colors which maximize both brightness and contrast are white, green, and red; therefore, those colors were selected for identification of whooping cranes in the EMP. All 3 of these base colors must appear on each bird. Any reported combinations without all 3 base colors are invalid; therefore, the rule provides an accuracy check during reading and a partial check for any missing bands. The system using only the 3 base colors has both high brightness and contrast and is unique (easily distinguished from all other existing combinations) with 168 1-transmitter and 36 (without duplicates) 2-transmitter individual codes (Table 1, Appendix A).

Addition of more colors involves a tradeoff between band visibility (brightness) and band readability (color contrast). In 2010, when the population reached 100 individuals, a fourth color was added to provide more band combinations. The color selected was black, which maximized reading accuracy because it had high contrast, i.e., it could not be confused with any of the other 3 colors. Additional colors other than black could be misinterpreted under different lighting conditions or from long distances (e.g., blue as green, white as yellow). However, the disadvantage of black was lower visibility than any other color. That drawback was minimized by only using black on the transmitter (long) bands and not for short bands (see below). Addition of the secondary color black provided 108 additional

Table 1. Numbers of available color-band identification codes in banding system of the reintroduced Eastern Migratory Population of whooping cranes, 2001-2017. Series name consists of the colors of the 2 bands carrying the VHF transmitter. W = white, G = green, R = red, B = black. All 3 base colors (W, G, R) must appear in each identification code.

Series	VHF only[a]	GSM/PTT[b]	Effective GSM/PTT[c]	Effective total
G[d]	16	4	0-4	16-20
G/R	20	10	0-10	20-30
G/W	20	10	0-10	20-30
R[d]	16	4	0-4	16-20
R/G	20	10	0-10	20-30
R/W	20	10	0-10	20-30
W[d]	16	4	0-4	16-20
W/G	20	10	0-10	20-30
W/R	20	10	0-10	20-30
Total GRW only	**168**	**72**	**36**	**204**
B[d]	12	0	0	12
B/G	16	4	4	20
B/R	16	4	4	20
B/W	16	4	4	20
G/B	16	4	4	20
R/B	16	4	4	20
W/B	16	4	4	20
Total GRW + B	**108**	**24**	**24**	**132**
Grand total	**276**	**96**	**60**	**336**

[a] VHF transmitter on 2 bands on 1 leg; 3 small bands and no transmitter on other leg.

[b] VHF transmitter on 2 bands on 1 leg; PTT or GSM on 2 bands on other leg.

[c] Unless the type of transmitter is included as part of the code, using a GSM/PTT code in a series that only consists of base colors results in unavailability of the duplicate code in another series; therefore, effective number of available codes is half the number of total codes in the single series.

[d] Series of a single color consist of 2 bands of the same color with attached transmitter.

1-transmitter and 24 2-transmitter combinations (Table 1, Appendix A). Like other combinations, the 3 base colors of white, green, and red must also appear on any bird with a combination containing black.

IDENTIFICATION CODING RULES

With the aforementioned color conditions as the foundation, the rules for assigning individual color combinations are as follows:

1. All 3 base colors (white, green, and red) must appear on each bird.
2. Small bands are base colors only (e.g., no small bands are black).
3. No small bands of the same color may appear consecutively. Large bands of the same color may only occur consecutively in transmitter attachments in which the color combination required on the leg requires a single color, in which case the 2 bands of the same color were recorded as if 1 band in the assigned color code.
4. Currently, half of the color combinations with 2 bands per leg are not used because they duplicate combinations in other series (see further explanation below). This facilitates interpretation of public sightings which usually only report colors. However, the transmitters on the 2 legs are different in appearance (Fig. 2) and can be readily distinguished by project personnel. Therefore, more combinations could be made available by including the transmitter type (VHF or remote) as part of the identification code. Similarly, small and long (transmitter) bands are also easily distinguished; therefore, more combinations could be available if band type was always included as part of the color code. However, except in rare instances mainly early in the project, this option has not been used, and although only 2 small bands could be used in a color combination, currently 3 small bands are used.

DUPLICATE CODES

This system is most suited to 1 transmitter, here VHF, per bird. However, a second transmitter, here a remote type, was readily accommodated, although this greatly reduced the number of possible combinations and, additionally, with no more than 2 bands per leg, the color code in a series identified by the primary (VHF) transmitter was then duplicated in another series. This duplication occurred because the color code of the remote transmitter matched the series identified by a VHF transmitter (Table 1). Avoiding these duplicate colors was not absolutely necessary for accurate bird identification because whether or not a transmitter was attached was obvious, and the 2 types of transmitters (VHF or remote [PTT or GSM]) looked very different and could be easily distinguished by project field personnel; they were different shapes and the transmitter portion of the VHF units was painted (to code) while that of the remote units was not (Fig. 2). Originally, the band length (long vs. small) and type of transmitter were all part of the identification code. However, many project participants only reported and recorded colors. Additionally, the amount of data from sightings by the general public has greatly increased, and those do not distinguish types of transmitters. Therefore, few duplicate color combinations were used early in the project, and no duplicate color codes were used during the latter 10 years.

Earlier in the project, only 3-6 remote transmitters were attached to juveniles in the annual release cohort. In more recent years, most of the released birds have been equipped with remote transmitters. These units were used on young birds and prioritized to females because these age-sex classes often have unpredictable movement patterns in comparison to adults (Urbanek et al. 2010, 2014, 2018; Zimorski and Urbanek 2010). Typically, all remote transmitters were temporary and attached to juveniles with the intent of eventual replacement by small bands and a permanent identification color code after failure of the remote unit a few years later. Remote units were not essential for monitoring adults because those birds were typically territorial or exhibited consistent movement patterns and could be located by VHF tracking only. Planning ahead by reserving codes with the correct cohort identification (color code on VHF transmitter) was necessary to accommodate this change from temporary to permanent identification code. Except for this special accommodation for remote transmitters, the released bird retained its original color code for the remainder of its life, greatly simplifying record keeping and reducing errors in reported observations.

RECYCLING CODES

This system uses no numbers. Engraved numbers are only marginally compatible with these bands, and most importantly, numbers are much less readable than colors on leg bands of cranes at the distances, through obstructing vegetation, and during crane movements typical of field conditions in which observations are recorded. Because codes are color only and number of colors is minimized, this limits the number of available codes; therefore, codes of cranes no longer in the population must be reused. This is readily accomplished in this reintroduction because the population is small and the cranes were closely monitored. However, it is critical that there be only 1 project staff member responsible for assigning codes and that individual constantly tracks mortalities and any other removals to keep the list of available codes up to date. Codes of birds of uncertain status (i.e., missing) are not again made available until the crane has not been recorded as alive for more than 1 year for well-monitored birds or 2 years for birds summering outside Wisconsin. Through 2017, there have been no cases in which codes were erroneously reused as a result of these criteria (i.e., no cranes that had been classified as dead after being missing then later reappeared still alive).

MANAGEMENT IMPLICATIONS

The color-band system described here has provided well-organized and meaningful identification and formed the basis of data collection, reporting, management, and critically important analysis for this reintroduction. If the banding system continues to be operated according to current rules, no changes will be needed in the near future. It is possible that the population could increase to numbers resulting in need for an additional secondary color (5 colors total) before the reintroduction phase of the project is completed. If at some point the reintroduction is successful and radiotracking of all birds is no longer necessary (i.e., transmitters are not required on all birds), 3 small color bands could be used on each leg to greatly increase the number of possible combinations for additional identification codes. The system could be used to maintain continuity in identification of EMP whooping cranes as long as monitoring of the reintroduced population is needed and certainly until the population becomes self-sustaining.

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Appendix A. Examples of the 4 series types in the color-code identification system of the reintroduced Eastern Migratory Population of whooping cranes. L = long (transmitter) bands, G = green, W = white, R = red, B = black, REM = remotely tracked transmitter (satellite or cellular); other transmitters on long (L) bands are VHF. There are 372 or 336 color codes including or excluding duplicate codes, respectively, in this 4-color system.

Code ID	Color code	Duplicate code ID	Duplicate color code
Base colors only, 2-color series ID (GW,WG,RW,WR,RG,GR)[a]			
GW01	L G/W:L R(REM)	R11	L G/W(REM):L R
GW02	L G/W:L R/W(REM)	RW17	L G/W(REM):L R/W
GW03	L G/W:L R/G(REM)	RG17	L G/W(REM):L R/G
GW04	L G/W:L W/R(REM)	WR17	L G/W(REM):L W/R
GW05	L G/W:L G/R(REM)	GR17	L G/W(REM):L G/R
GW06	L G/W:R/G/W		
GW07	L G/W:W/R/W		
GW08	L G/W:G/R/W		
GW09	L G/W:R/W/G		
GW10	L G/W:W/R/G		
GW11	L G/W:G/R/G		
GW12	L G/W:G/W/R		
GW13	L G/W:R/W/R		
GW14	L G/W:W/G/R		
GW15	L G/W:R/G/R		
Base colors only, 1-color series ID (W,G,R)[b]			
G01	L G:L R/W(REM)	RW16	L G(REM):L R/W
G02	L G:L W/R(REM)	WR16	L G(REM):L W/R
G03	L G:R/G/W		
G04	L G:W/R/W		
G05	L G:G/R/W		
G06	L G:R/W/G		
G07	L G:W/R/G		
G08	L G:G/W/R		
G09	L G:R/W/R		
G10	L G:W/G/R		
Contains secondary color, 2-color series ID (BW, WB, BG,GB,BR,RB)[c]			
BW01	L B/W:L R/G(REM)		
BW02	L B/W:L G/R(REM)		
BW03	L B/W:R/G/W		
BW04	L B/W:G/R/W		
BW05	L B/W:R/W/G		
BW06	L B/W:W/R/G		
BW07	L B/W:G/R/G		
BW08	L B/W:G/W/R		
BW09	L B/W:W/G/R		
BW10	L B/W:R/G/R		
Contains secondary color, 1-color series ID (B)[d]			
B01	L B:R/G/W		
B02	L B:G/R/W		
B03	L B:R/W/G		
B04	L B:W/R/G		
B05	L B:G/W/R		
B06	L B:W/G/R		

[a] 30 codes in GW series, GW16-30 are same as GW01-15 only with legs reversed.
[b] 20 codes in G series, G11-20 same as G01-10 only with legs reversed.
[c] 20 codes in BW series, BW11-20 same as BW01-10 only with legs reversed.
[d] 12 codes in B series, B07-B12 are same as B01-06 only with legs reversed.