Notes

Annual Survival Rate Estimate of Satellite Transmitter–Marked Eastern Population Greater Sandhill Cranes

David L. Fronczak,* David E. Andersen, Everett E. Hanna, Thomas R. Cooper

D.L. Fronczak, T.R. Cooper
U.S. Fish and Wildlife Service, Migratory Bird Management, 5600 American Boulevard West, Suite 960, Bloomington, Minnesota 55437

D.E. Andersen
U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, 200 Hodson Hall, 1980 Folwell Avenue, St. Paul, Minnesota 55108

E.E. Hanna
Long Point Waterfowl, P.O. Box 160, 115 Front Street, Port Rowan, Ontario, N0E 1M0

Abstract

Several surveys have documented the increasing population size and geographic distribution of Eastern Population greater sandhill cranes *Grus canadensis tabida* since the 1960s. Sport hunting of this population of sandhill cranes started in 2012 following the provisions of the Eastern Population Sandhill Crane Management Plan. However, there are currently no published estimates of Eastern Population sandhill crane survival rate that can be used to inform harvest management. As part of two studies of Eastern Population sandhill crane migration, we deployed solar-powered global positioning system platform transmitting terminals on Eastern Population sandhill cranes ($n = 42$) at key concentration areas from 2009 to 2012. We estimated an annual survival rate for Eastern Population sandhill cranes from data resulting from monitoring these cranes by using the known-fates model in the MARK program. Estimated annual survival rate for adult Eastern Population sandhill cranes was 0.950 (95% confidence interval = 0.885–0.979) during December 2009–August 2014. All fatalities ($n = 5$) occurred after spring migration in late spring and early summer. We were unable to determine cause of death for crane fatalities in our study. Our survival rate estimate will be useful when combined with other population parameters such as the population index derived from the U.S. Fish and Wildlife Service fall survey, harvest, and recruitment rates to assess the effects of harvest on population size and trend and evaluate the effectiveness of management strategies.

Keywords: survival; Eastern Population; annual; satellite telemetry; known-fate; sandhill crane

Received: April 7, 2015; Accepted: July 17, 2015; Published Online Early: July 2015; Published: December 2015

Citation: Fronczak DL, Andersen DE, Hanna EE, Cooper TR. Annual survival rate estimate of satellite transmitter–marked eastern population greater sandhill cranes. 2015. *Journal of Fish and Wildlife Management* 6(2):464–471; e1944-687X. doi: 10.3996/042015-JFWM-035

* Corresponding author: dave_fronczak@fws.gov

Introduction

The Eastern Population (EP) of greater sandhill cranes *Grus canadensis tabida* (hereafter cranes) has increased in size and expanded its breeding range over the past half century (Amundson and Johnson 2011). Both the U.S. Fish and Wildlife Service (USFWS) fall crane survey and the North American Breeding Bird Survey provide evidence of this growth (Amundson and Johnson 2011). Concerns over damage to agricultural crops and

an interest in providing hunting opportunity have increased over the past decade in many states and provinces within the range and have resulted in the Atlantic and Mississippi flyways developing a management plan for cranes that contains provisions for sport hunting (Van Horn et al. 2010). Hunting seasons have recently opened in Kentucky (2011) and Tennessee (2013) following the frameworks contained in the management plan. However, estimates of survival rate for cranes that could be used to inform harvest management are lacking, constraining the development of population models (e.g., Miller et al. 1972).

There are few published estimates of vital rates for after-hatch-year (hereafter adult) migratory cranes, and most estimates are derived from studies of populations other than the EP. Drewien et al. (1995) indirectly derived annual survival rate estimates for the Rocky Mountain Population of cranes of 0.95, 0.94, and 0.91 for 1972–85, 1985–90, and 1990–92, respectively, by using a population model. The only estimates of annual survival rate for cranes comes from Nesbitt and Moore (*in* Tacha et al. 1994), who estimated annual survival rates of 0.858 and 0.874 during a mark–resight study for adult female and male cranes, respectively, during the winter in Florida from 1980 to 1989. The same study estimated annual survival rate for the Florida Population of nonmigratory cranes *Grus canadensis pratensis* at 0.918 and 0.884 for adult females and males, respectively. Co-currently, Bennett and Bennett (1990) used radiotelemetry to estimate a mean annual survival rate of 0.89 for the period from 1986 to 1989 for the Florida Population of nonmigratory cranes at Okefenokee Swamp in southeastern Georgia.

As part of two separate studies focusing on crane ecology (Fronczak 2014; Hanna et al. 2014), we marked adult cranes with global positioning system (GPS) platform transmitting terminals (PTTs) and used the resulting monitoring data to estimate annual survival rate. We marked cranes across the EP breeding distribution and estimated a survival rate based on monthly intervals from December 2009 to August 2014. Our survival rate estimate will be useful when combined with other population parameters to reassess the effects of harvest on population size and trend and evaluate the effectiveness of management strategies (e.g., USFWS, Environmental Assessment: proposed hunting of cranes [USFWS 2011]).

Study Area

We captured and marked cranes throughout their annual migratory cycle at seven sites within the known EP range (Tacha et al. 1994; Figure 1) during 2009–2012. We conducted the majority of our trapping at the Jasper–Pulaski Fish and Wildlife Area (FWA), northwestern Indiana (41.2°N, −86.9°W) and the Hiwassee Wildlife Refuge (WR), southeastern Tennessee (35.4°N, −85.0°W); both areas are considered major staging areas for cranes (Fronczak 2014). In addition to these three primary sites, we trapped and placed satellite transmitters on cranes at Goose Pond Fish and Wildlife Area, Indiana (39.0°N, −87.2°W); Sherburne National Wildlife Refuge, Minnesota (45.5°N, −93.8°W); Crex Meadows Wildlife Area, Wisconsin (45.8°N, −92.6°W); and Hop-In Wildlife Refuge, Tennessee (33.3°N, −89.0°W). Similar to both Jasper–Pulaski FWA and the Hiwassee WR, these state- and federal agency–managed areas provide sufficient protected roosting and feeding habitats (i.e., agricultural landscape and crops produced for wildlife consumption) for cranes to stage, stopover, and winter. However, cranes do not concentrate or stopover at these sites to the extent they do at either Jasper–Pulaski FWA or Hiwassee WR. We also captured and marked cranes at a Canadian staging site at Manitoulin Island, Ontario (45.8°N, −82.2°W) as part of a separate ecology study (Hanna et al. 2014).

Methods

Trapping

Eastern Population sandhill cranes occur across broad geographic areas during both summer and winter and exhibit variation in timing of migration across their range. To mark a representative sample of EP cranes with PTTs, we used a strategy similar to that used by Krapu et al. (2011) in a comparable study of Mid-continent Population cranes. We identified Jasper–Pulaski FWA and Hiwassee WR as the major staging areas used during migration by EP cranes, based on previous studies that described migratory routes (Walkinshaw 1960; Crete and Toepfer 1978), EP abundance surveys (e.g., Mississippi Flyway Cooperative Midwinter Survey and state periodic surveys), and subsequent behavior of cranes we marked in this study. For each stopover area, we selected trapping periods before, during, and after estimated peak abundance based on periodic surveys of cranes (J. Bergens, Indiana Department of Natural Resources, unpublished data and R. Klippel, Tennessee Wildlife Resource Agency, unpublished data) during fall migration. We used this capture protocol to mark a representative sample of cranes and to capture the temporal variation in EP crane movements through these stopover areas. In addition, we captured EP cranes on alternative staging areas (Sherburne National Wildlife Refuge, Minnesota; Crex Meadows Wildlife Area, Wisconsin; Hop-In Wildlife Refuge, Tennessee; Goose Pond Fish and Wildlife Area, Indiana) to include cranes from portions of their distribution that may not have been represented by cranes we trapped at Jasper–Pulaski FWA or Hiwassee WR. We trapped and marked EP cranes on Manitoulin Island, Ontario, as a part of a separate study of crane autumn foraging and migratory ecology (Hanna et al. 2014).

We used a rocket-propelled net assembly as the primary method to capture EP cranes. We identified potential trapping sites by using the protocol developed for rocket netting Mid-continent Population cranes by Krapu et al. (2011). Their protocol gives priority to daytime loafing sites with more than 20 cranes present in pasture or other open land-cover types followed by the use of decoys. We modified their protocol by baiting loafing sites with whole-kernel corn, and when cranes responded to bait for two consecutive days, we

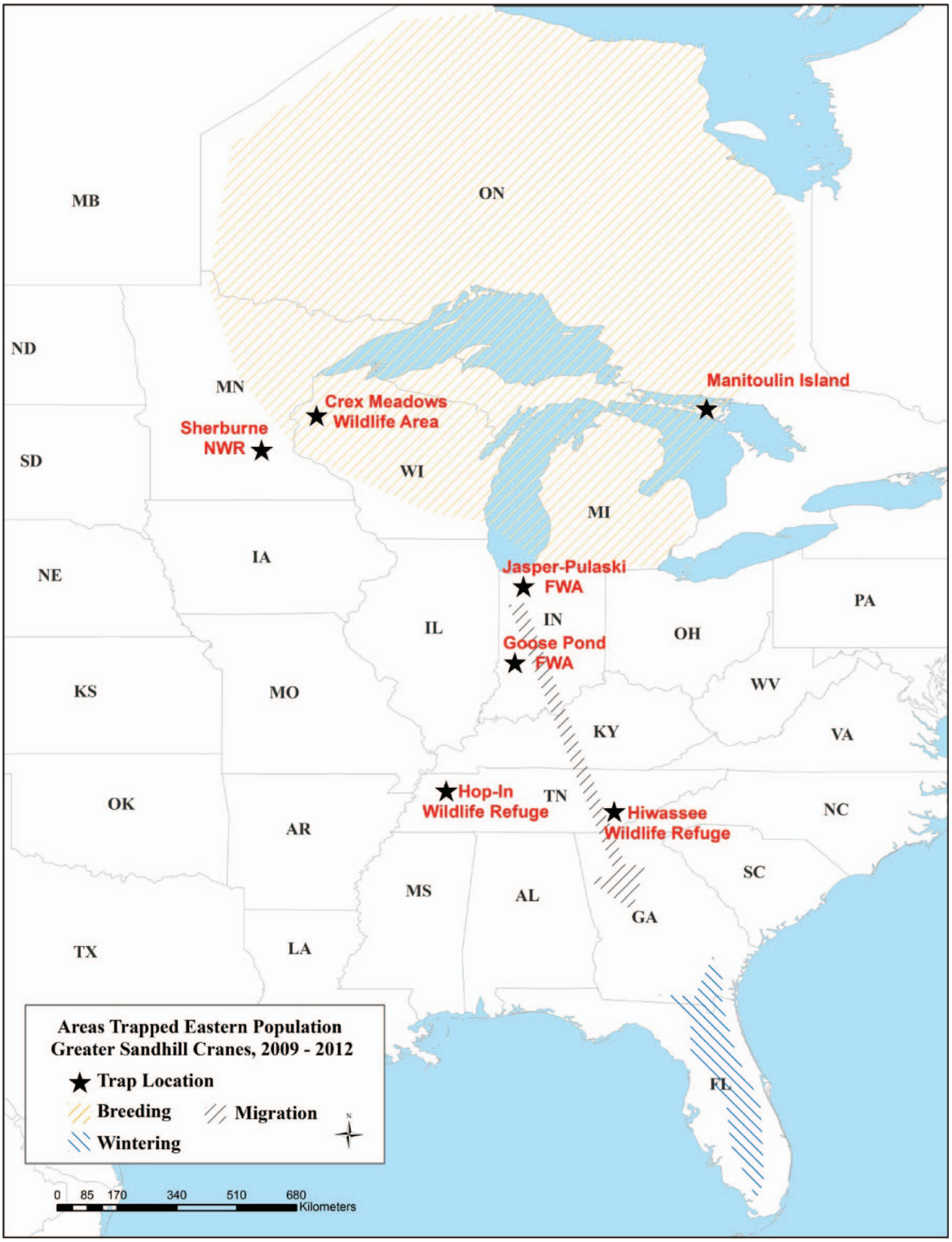

Figure 1. Trapping locations for Eastern Population sandhill cranes *Grus canadensis tabida*. Cranes were marked with platform transmitting terminals in the states of Minnesota, Wisconsin, Indiana, and Tennessee and the province of Ontario, following the depiction of Tacha et al. (1994) of breeding and wintering distribution and major migration routes. Trapping was conducted during sandhill crane spring (March) and fall (October - December) migration periods and during the wintering periods (December - January), 2009 - 2012.

assembled a 13.1 × 19.7 m rocket-propelled net (Wheeler and Lewis 1972; D. Brandt, U.S. Geological Survey [USGS], Northern Prairie Wildlife Research Center, personal communication) at a potential capture location. We conducted trapping primarily in the morning because cranes consistently returned to baited sites after leaving nocturnal roosts. We targeted affixing PTTs to adult female cranes that we observed as part of

a family group or as a member of a mated pair. We targeted female cranes because they are more likely to return to natal breeding grounds the following spring (Walkinshaw 1949; Drewin 1973) than males. We identified adult female cranes based on the physical and social characteristics described by Tacha (1998) as smaller body–sized cranes, with red skin on the crown of the head, more likely to be viewed as following larger body–sized male cranes, and less likely to display agnostic behaviors. However, following capture, if we could not identify family groups, we selected a smaller-bodied adult crane that we presumed to be a female.

For each PTT-marked bird in our sample, we drew blood from the vein below the tibio-tarsus and placed samples in a lysis buffer anticoagulant solution (Jones et al. 2005). Blood was subsequently analyzed by Avian Biotech International (Tallahassee, FL) to determine sex. We did not collect blood samples for nine PTT-marked cranes during the Manitoulin Island ecology study. We affixed a 30-g, three-solar–paneled GPS satellite PTT (North Star Science and Technology LLC, Baltimore, MD) to captured cranes via flanged leg bands. We mounted PTTs on a 7.6-cm, two-piece color-coated polyvinyl chloride, alpha-numeric–coded engraved leg band (Haggie Engraving, Crumpton, MD). We reinforced the connection between the antenna and the transmitter housing with J-B Weld (J-B Weld, Sulphur Springs, TX) as a precaution, because it is known as a weak point and a cause for loss of transmission (D. Brandt, personal communication). We attached leg bands above the distal tibio-tarsus joint (Krapu et al. 2011). Flanged auxiliary markers and PTTs together weighed approximately 80 g; less than or equal to 2% of average body mass at capture and under the 3% of body mass guidelines recommended by the USGS Bird Banding Laboratory (USGS 2012). For cranes not marked with PTTs, we affixed a 7.6-cm, 1.5-wrapped alpha-numeric–coded engraved polyvinyl chloride tarsus auxiliary leg band above the distal tibio-tarsus joint. All birds captured received size 8 USGS Bird Banding Laboratory butt-end aluminum bands. When more than two cranes per crew member were captured at one time, we released cranes in excess of that number immediately without processing to avoid detrimental handling effects (e.g., myopathy). We released all cranes held for processing as a group within 30 min of being captured.

In addition to using a rocket-propelled net, we used a Coda NetLauncher (Coda Enterprises Inc., Mesa, AZ) to capture cranes in locations where using a rocket-propelled net was not feasible. We followed the standard Coda NetLauncher protocol developed for cranes by the Ohio Department of Natural Resources (D. Sherman, Ohio Department of Natural Resources, personal communication). We also used modified Victor #3 softcatch leghold traps as described by King et al. (1998) and used these to capture one crane at Hiwassee WR. We captured cranes under University of Minnesota Institutional Animal Care and Use Committee protocol 1103A97333 and University of Western Ontario Animal Use protocol 2010-213.

Platform transmitting terminals collected GPS location data that were transmitted to satellites for each duty cycle through standard Doppler technology. Accuracy for GPS locations was classified into four quality levels: less than 26 m, 26–50 m, 51–75 m, and 76–100 m. Platform transmitting terminal units were programmed to maximize the number of GPS locations per day, which afforded the ability to determine the status (i.e., sedentary locations or continuous movement) of PTT-marked cranes.

Data analysis

We calculated survival rate estimates using the Kaplan–Meier product estimator through the known-fates model in the MARK program (White and Burnham 1999) for PTT-marked cranes based on the period between December 2009 and August 2014 (the initiation and termination of our study). The known-fates model is commonly used with telemetry data (Roth et al. 2005; Borkhataria et al. 2012) and assumes that the resighting probability is equal to 1, that marking does not affect individual fates, that fates among individuals are independent, and that censoring is unrelated to mortality (White and Burnham 1999). We constructed monthly binary encounter histories (Data S1, *Supplemental Material*) for each PTT-marked crane based on the White and Burnham (1999) LDLDLDLD, live (L)-dead (D) encounter format for entry into MARK. We right censored an interval when we did not receive a signal, and if locations before loss of transmission were continuous and indicated movement consistent with normal behavior. We assigned death to an interval when we recovered a PTT from a deceased crane, or if PTT locations before loss of transmission indicated sedentary locations more than two duty cycles (or $>$6 d). We used more than two duty cycles as a threshold because we did not observe similar behavior in cranes that were known to be alive. We estimated survival rate based on monthly intervals and considered three models for our sample group: 1) survival rate constant across time, 2) survival rate varying annually (December–November), and 3) survival rate varying monthly. We evaluated models using Akaike's Information Criterion (AIC) and selected our best-supported model based on ΔAIC*c*, based on small sample size (ΔAIC*c*) (Burnham and Anderson 2002).

Results

We deployed PTTs on 42 adult EP cranes between 2009 and 2012 (female, n = 25; male, n = 6; undetermined, n = 11), and we recovered PTTs from four marked cranes that died and redeployed their PTTs on four additional cranes. In total, eight (19%) PTT-marked cranes remained in "alive" status, five (12%) cranes died, and we right censored 28 (66%) PTTs during our study period. We incorporated 57 monthly encounter histories of PTT-marked cranes into survival analysis in MARK. The model assuming constant survival through time and resulting an annual survival estimate of 0.950 (95% confidence interval = 0.885–0.979) was the best-

Table 1. Comparison of Akaike's Information Criterion, corrected for small sample size (AIC*c*) values for known-fates models (constant, year, month) for platform transmitting terminal–marked adult Eastern Population sandhill cranes *Grus canadensis tabida* from 2009 to 2014. Models are ranked by ΔAIC*c*.

Model	ΔAIC*c*	AIC*c* weight	No. of parameters	Deviance
Constant	0.000	0.954	1	23.222
Year	6.085	0.046	5	21.259
Month	94.657	0.000	57	0.000

supported model among the models we considered (Table 1).

We marked 24 cranes with PTTs during the first year of our study, and none of these cranes died or were right censored during that year (Table 2). During the second year of our study, we captured and marked 13 additional cranes, 2 (5%) PTT-marked cranes died, and we right censored 4 (10%) PTT-marked cranes. From the start of the third year of our study to the end of August 2014, we captured and affixed PTTs to 4 (10%) cranes, 3 (7%) cranes died, and we right censored 24 (57%) marked cranes. Based on our analysis of movement data, signal loss, most likely due to antenna separation, was the main reason for PTT-marked cranes to be right censored. To avoid violating the assumption that marking did not affect individual fates, we right-censored data for one PTT-marked crane at the time it arrived on its summer area, where we determined an injury associated with the PTT most likely occurred. We also excluded two cranes from our survival analyses; one crane died 3 d after capture and we assumed that that fatality was related to capture, and we assumed PPT failure for the second crane, losing the transmission signal approximately 3 mo after being trapped.

Discussion

There are few survival rate estimates derived from marked individuals for North American sandhill cranes, particularly for *G. c. tabida*. As part of two studies of EP crane migration ecology, we estimated a constant survival rate during a more than 4-y period from December 2009 through August 2014. Our survival rate estimate for adult EP cranes of 0.950 (95% confidence interval = 0.885–0.979) was comparable to indirect and derived adult survival rate estimates for Rocky Mountain Population greater sandhill cranes that ranged from 0.91 to 0.95 (Drewien et al. 1995) and higher than 0.858 and 0.874 for female and male wintering EP cranes estimated from mark–resight observations in Florida during 1980–1989 (from Nesbitt and Moore *in* Tacha et al. 1994). However, Nesbitt and Moore's (*in* Tacha et al. 1994) survival rate estimates were derived from EP cranes marked only in Florida, so it is not clear how well those estimates represent survival rates for the EP as a whole.

The count from the USFWS coordinated fall survey is the current measure used to track the population trend of EP cranes. This survey has documented a long-term increase in EP cranes with an initial count of 14,385 cranes in 1981 and has increased to 83,479 cranes in 2014 (S. Kelly, USFWS, personal communication). The increase in EP crane population can be explained by protection from hunting, restoration and management of wetland habitat (Van Horn et al. 2010), and high adult survival. Avian diseases and trauma (e.g., power line collisions and injury resulting from catastrophic weather events) are thought to be the most common sources of nonhunting mortality for adult sandhill cranes (Windingstad 1988). Bennett and Bennett (1990) found that predation from bobcats *Lynx rufus* and an alligator *Alligator mississippiensis* were the main cause of death for radio-marked adult Florida Population of sandhill cranes in the Okefenokee Swamp, Georgia. We identified fatality of marked EP cranes in our study occurred during the spring (March, $n = 2$ and April, $n = 2$) and summer (June, $n = 1$) and in northern latitudes, where predators such as bobcats maybe less abundant. We were unable to ascertain the cause of death of cranes in our study due to the amount of time between determining that mortality had occurred (i.e., sedentary movements over more than two duty cycles) and our ability to coordinate a carcass recovery effort. We concluded that one crane died due to capture myopathy based on the short period between capture and fatality (i.e., 3 d). We also recovered one crane to address an issue with a broken flange on the PTT assembly. Photographs from birdwatchers at Jasper–Pulaski FWA (Figure 2) and our study site at Manitoulin Island confirmed that antenna separation from the PTT was a cause of signal loss for multiple cranes.

Table 2. Fate summary (alive, dead, and right censored) for platform transmitting terminal–marked Eastern Population sandhill cranes *Grus canadensis tabida* for periods from December through the following November, 2009–2013, and December through the following August, 2013–2014.

Status	2009–10	2010–11	2011–12	2012–13	2013–14
Alive	24	31	27	10	8
Dead	0	2	2	1	0
Right censored	0	4	6	17	1

Harvest opportunity for EP sandhill cranes has resumed in Kentucky and Tennessee, and there has been increased interest in establishing additional hunting seasons, particularly within the EP breeding range. Our survival rate estimate will be useful when combined with other population parameters, such as the population index derived from the USFWS fall survey, harvest estimates, and recruitment rates to assess the effects of harvest on cranes and to evaluate the effectiveness of current management strategies (USFWS 2011). Drewien et al. (1995) noted that long-term marking programs to evaluate survival are absent for most hunted crane populations. We present the first survival rate estimate for adult cranes during a 4-y period from 2009 to 2014, which can be used to help inform management of cranes. We also recognize that survival rates may fluctuate due to changes in harvest and environmental conditions and suggest the establishment of a monitor-

Figure 2. Eastern Population sandhill crane *Grus canadensis tabida* with platform transmitting terminal (PTT) antenna separated from transmitter housing (missing antenna indicated by red circle). The sandhill crane was PTT marked December 2010, and the last transmission for this unit was received August 2013. Photo was taken in Jasper County, Indiana, November 2013. Photo credit: Bob Huguenard.

ing program for crane survival rate on an annual basis that would provide important information that could be used to inform crane management.

Supplemental Material

Please note: The *Journal of Fish and Wildlife Management* is not responsible for the content or functionality of any supplemental material. Queries should be directed to the corresponding author for the article.

Data S1. Monthly binary life history table to calculate survival rate estimates for platform-transmitting terminal (PTT)–marked EP sandhill cranes *Grus canadensis tabida* by using Kaplan–Meier product estimator through the known-fate model in program MARK.

Found at DOI: http://dx.doi.org/10.3996/042015-JFWM-035.S1 (6 KB TXT).

Reference S1. Amundson CL, Johnson DH. 2011. Assessment of the Eastern Population of greater sandhill cranes *Grus canadensis tabida* fall migration survey, 1979–2009. Report to the U.S. Fish and Wildlife Service, Region 3, Bloomington, Minnesota.

Found at DOI: http://dx.doi.org/10.3996/042015-JFWM-035.S2 (433 KB PDF).

Reference S2. Crete RA, Toepfer JE. 1978. Migration of radio-tagged eastern greater sandhill cranes. Report submitted to the U.S. Fish and Wildlife Service, Region 3, Bloomington, Minnesota.

Found at DOI: http://dx.doi.org/10.3996/042015-JFWM-035.S3 (569 KB PDF).

Reference S3. U.S. Fish and Wildlife Service. 2011. Proposed hunting regulations for the Eastern Population of sandhill crane in the Mississippi Flyway. Washington, D.C.: Environmental Assessment.

Found at DOI: http://dx.doi.org/10.3996/042015-JFWM-035.S4 (1895 KB PDF).

Reference S4. Van Horn K, White T, Atkins W, Cooper T, Urbanek R, Holm D, Sherman D, Aborn D, Suckow J, Cleveland K, Brook R. 2010. Management plan for the Eastern Population of sandhill cranes. Mississippi and Atlantic Flyway Council Webless Committee, Bloomington, Minnesota.

Found at DOI: http://dx.doi.org/10.3996/042015-JFWM-035.S5 (349 KB PDF).

Acknowledgments

This research was supported by the USFWS, Webless Migratory Game Bird Program; the USGS, Northern Prairie Wildlife Research Center and Minnesota Cooperative Fish and Wildlife Research Unit; the USFWS, Region 3, Migratory Bird Management Office; Long Point Waterfowl; S.C. Johnsons and Son Ltd.; the Ontario Federation of Anglers and Hunters; the Canadian Wildlife Service; Wildlife Habitat Canada, and the TD Friends of the Environment Foundation.

We thank D. Brandt, P. Link, R. Klippel, J. Jackson, B. Swiney, S. Shelby, J. Womac, B. Layton, D. Sherman, B. Feaster, A. Phelps, R. Ronk, J. Bergens, J. Gilbert, E. Carroll, R. Knopick, W. Delks, V. Clarkston, E. Hockman, C. Trosen, A. Johnson, C. Kanke, P. Peterson, S. Zudrow, T. Paulson, W. Tamminga, J. Brunjes, E. Harper, L. Armstrong, T. White, M. Morse, S. Bossuyt, M. Bossuyt, A. Dhamorikar, J.E. Hanna, K. Weaver, and S. Petrie for field assistance. We thank R. Russell and R. Brook for comments on previous drafts of this manuscript. We also thank the Associate Editor, and the two anonymous reviewers from the *Journal of Fish and Wildlife Management* for constructive suggestions for improving the manuscript. The project was supported through Research Work Order 86 at the USGS Minnesota Cooperative Fish and Wildlife Research Unit at the University of Minnesota.

Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. Government or the University of Minnesota.

References

Amundson CL, Johnson DH. 2011. Assessment of the Eastern Population of greater sandhill cranes (*Grus canadensis tabida*) fall migration survey, 1979–2009. Report to the U.S. Fish and Wildlife Service, Region 3, Bloomington, Minnesota (see *Supplemental Material*, Reference S1, http://dx.doi.org/10.3996/042015-JFWM-035.S2).

Bennett AJ, Bennett LA. 1990. Survival rates and mortality factors of Florida sandhill cranes in Georgia. North American Bird Bander 15:85–88. Available: https://sora.unm.edu/sites/default/files/journals/nabb/v015n03/p0085-p0088.pdf (May 2015).

Borkhataria RR, Frederick PC, Keller RA, Collazo JA. 2012. Temporal variation in local wetland hydrology influences postdispersal survival of juvenile wood storks (*Mycteria Americana*). Auk 129:517–528. Available: http://www.bioone.org/doi/full/10.1525/auk.2012.11244 (May 2015).

Burnham KP, Anderson DR. 2002. Model selection and multimodel inference: a practical information theoretic approach. 2nd edition. New York: Springer-Verlag.

Chapman LJ, Putnam DF. 1973. The physiography of southern Ontario. 2nd edition. Toronto: University of Toronto Press.

Crete RA, Toepfer JE. 1978. Migration of radio-tagged eastern greater sandhill cranes. Report submitted to the U.S. Fish and Wildlife Service, Region 3, Bloomington, Minnesota (see *Supplemental Material*, Reference S2, http://dx.doi.org/10.3996/042015-JFWM-035.S3).

Drewien RC, Brown WM, Kendall WL. 1995. Recruitment in Rocky Mountain greater sandhill cranes and comparison with other crane populations. Journal of Wildlife Management 59:339–356. Available: http://www.jstor.org/stable/3808948?seq=1#page_scan_tab_contents (May 2015).

Fronczak DL. 2014. Distribution, migration chronology, and survival rates of Eastern Population sandhill cranes. Master's thesis. St. Paul, Minnesota: University of Minnesota. Available: http://mncoopunit.cfans.umn.edu/files/2015/03/EP-Sandhill-Crane-Thesis-Fron-11-20-2014.pdf (May 2015).

Hanna EE, Schummer ML, Petrie SA. 2014. Migratory chronology, autumn recruitment, and population size of Eastern Population sandhill crane (*Grus canadensis*) from the North Shore Region of Lake Huron, Ontario, Canada. An interim technical report for the Canadian Wildlife Service and Ontario Ministry of Natural Resources, Port Rowan, Ontario. Available: http://longpointwaterfowl.org/wp-content/uploads/2011/05/Hanna-et-al.-2014-Migratory-chronology-autumn-recruitment-and-population-size-of-Eastern-Population-Sandhill-Cranes1.pdf (May 2015).

Jones KL, Krapu GL, Brandt DA, Ashley MV. 2005. Population genetic structure in migratory sandhill cranes and the role of Pleistocene glaciations. Molecular Ecology 14:2645–2657. Available: http://onlinelibrary.wiley.com/doi/10.1111/j.1365-294X.2005.02622.x/abstract;jsessionid=106EA0F4EFFCA0C0FE7FEC5A7E63FE1F.f01t01 (May 2005).

King DT, Paulson JD, Leblanc DJ, and Bruce K. 1998. Two capture techniques for American white pelicans and great blue herons. Colonial Waterbirds 21:258–260.

Available: http://www.jstor.org/stable/1521917?seq=1#page_scan_tab_contents.

Krapu GL, Brandt DA, Jones KL, Johnson DH. 2011. Geographic distribution of the Mid-continent Population of sandhill cranes and related management applications. Wildlife Monographs 175:1–38. Available: http://www.bioone.org/doi/abs/10.1002/wmon.1 (May 2015).

Miller RS, Hochbaum GS, Botkin DB. 1972. A simulation model for the management of sandhill cranes. Bulletin 80. New Haven, Connecticut: Yale University, School of Forestry and Environmental Studies.

Roth TC II, Lima SL, Vetter WE. 2005. Survival and causes of mortality in wintering sharp-shinned hawks and Cooper's hawks. Wilson Bulletin 117:237–244. Available: http://www.bioone.org/doi/abs/10.3356/JRR-10-55.1 (May 2015).

Tacha TC, Nesbitt SA, Vohs PA. 1994. Sandhill crane. Pages 77–94 in Tacha TC, Braun CE, editors. Migratory shore and upland game bird management in North America. Lawrence, Kansas: Allen Press.

Tacha TC. 1998. Social organization of sandhill cranes from midcontinental North America. Wildlife Monographs 99:3–37. Available: http://www.jstor.org/stable/3830635?seq=1#page_scan_tab_contents.

[USFWS] U.S. Fish and Wildlife Service. 2011. Proposed hunting regulations for the Eastern Population of sandhill crane in the Mississippi Flyway. Washington, D.C.: Environmental Assessment (see *Supplemental Material*, Reference S3, http://dx.doi.org/10.3996/042015-JFWM-035.S4).

[USGS] U.S. Geological Survey. 2012. Auxiliary marking authorization. Bird Banding Laboratory. Available: www.pwrc.usgs.gov/bbl/homepage/aux_mark_auth.cfm (January 2013).

Van Horn K, White T, Atkins W, Cooper T, Urbanek R, Holm D, Sherman D, Aborn D, Suckow J, Cleveland K, Brook R. 2010. Management plan for the Eastern Population of sandhill cranes. Mississippi and Atlantic Flyway Council Webless Committee, Bloomington, Minnesota (see *Supplemental Material*, Reference S4, http://dx.doi.org/10.3996/042015-JFWM-035.S5).

Walkinshaw LH. 1949. Cranes of the world. New York: Winchester Press.

Walkinshaw LH. 1960. Migration of the sandhill crane east of the Mississippi River. Wilson Bulletin 72:358–384. Available: https://sora.unm.edu/node/127838 (May 2015).

Wheeler RH and Lewis RH. 1972. Trapping techniques for sandhill crane studies in the Platte River Valley. U.S. Department of the Interior, U.S. Fish and Wildlife Service, Natural Resource Publication 107.

White GC, Burnham KP. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement:120–138. Available: http://www.researchgate.net/publication/216771416_Program_MARK_Survival_estimation_from_populations_of_marked_animals (May 2012).

Windingstad RM. 1988. Nonhunting mortality in sandhill cranes. Journal of Wildlife Management 52:260–263. Available: http://www.researchgate.net/publication/271694406_Nonhunting_Mortality_in_Sandhill_Cranes (May 2015).