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POPULATION STATUS AND GEOGRAPHIC DISTRIBUTION OF GREATER SANDHILL CRANES IN THE MID-CONTINENT POPULATION

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POPULATION STATUS AND GEOGRAPHIC DISTRIBUTION OF GREATER SANDHILL CRANES IN THE MID-CONTINENT POPULATION

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Abstract: Number and geographic distribution of greater sandhill cranes (*Grus canadensis tabida*) in the mid-continent population (MCP) of sandhill cranes were evaluated. *G. c. tabida* comprised 7 of 133 (5.3%) individuals of 3 subspecies which projects to 31,579 ± 11,661 (SE) individuals in an estimated spring MCP of 600,000 cranes. From a platform transmitting terminal (PTT)-marked sample representative of the geographic distribution of *G. c. tabida*, 10 of 13 (77%) settled during the breeding season in east-central Canada/Minnesota, including 4 in northwestern Minnesota, 4 in Manitoba (2 at sites near the Minnesota border), and 2 in Ontario. Three (23%) cranes settled in west-central Canada (1 in Saskatchewan and 2 in Alberta). From a sample of 16 VHF-radioed *G. c. tabida* representative of MCP distribution during 2003-2006, 11 (69%) and 5 (31%) originated from breeding grounds in east-central Canada and west-central Canada, respectively. Eight of 13 (62%) PTT-marked *G. c. tabida* settled in transition areas between the temperate prairies, and the mixed woods shield and the boreal plain ecological regions during the breeding season. Breeding distributions of PTT-marked *G. c. tabida* overlapped with *G. c. rowani* extensively in east-central Canada and Minnesota. All PTT-marked *G. c. tabida* that settled on breeding grounds in Canada staged in areas open to sport hunting in Saskatchewan, Manitoba, and North Dakota during fall; mean arrival and departure dates from staging areas were 7 September and 19 October (n = 12), for an average stay of 40 ± 4 (SE) days. *G. c. tabida* that spent the breeding season in Minnesota stayed in Minnesota during fall and experienced less exposure to hunting seasons over the fall/winter period than cranes breeding in Canada (26%, n = 3, vs. 55%, n = 8). A reduction in *G. c. tabida* harvest likely would be required for sandhill cranes to move beyond their current status as an occasional breeder across most of the northern plains, including the Prairie Pothole Region.

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Key words: breeding distribution, greater sandhill crane, *Grus canadensis tabida*, hunting mortality, mid-continent population, migration, population size, wintering grounds.

The mid-continent population (MCP) of sandhill cranes consists of 3 subspecies based on morphometry: greater sandhill crane (*Grus canadensis tabida*), lesser sandhill crane (*G. c. canadensis*), and Canadian sandhill crane (*G. c. rowani*) (Johnson and Stewart 1973). Of the 3 subspecies, the least information exists for *G. c. tabida*. In 1997, a major research project on the MCP was initiated by the USGS Northern Prairie Wildlife Research Center at the request of sandhill crane managers in states of the Central Flyway to gather information needed on several key population parameters. The primary objectives were to identify the geographic distribution of the 3 subspecies of MCP sandhill cranes throughout the annual cycle, identify length and pattern of stay on fall staging areas and wintering grounds, and to measure annual recruitment rates of young into the fall population. This project provided an opportunity to also gain insight into numbers and geographic distribution of *G. c. tabida* in the MCP.

Historically, *G. c. tabida* nested throughout the Prairie Pothole Region (PPR), including major parts of North Dakota, South Dakota, and southern and central Saskatchewan and southwestern Manitoba (Walkinshaw 1949). The subspecies was extirpated from most of its breeding range in the late 19th and early 20th centuries due to uncontrolled hunting and habitat loss (Walkinshaw 1949). Hunting of sandhill cranes was prohibited following the enactment of the Migratory Bird Treaty Act in 1918. By the 1940s, *G. c. tabida* had begun to recover from population lows and reoccupy major parts of its former breeding range in the midwestern and western United States (Littlefield and Ryder 1968, Drewien and Bizeau 1974, Meine and Archibald 1996, Schlorff 2005). However, in North Dakota, South Dakota, and southern parts of Manitoba and Saskatchewan, few breeding attempts have been documented over the past 70 years. In North Dakota, for example, where the species nested widely in the

19th century (Johnson 1976), only 4 documented breeding records were reported from 1950 through 2007 (Fields et al. 1974, T. Grant, U.S. Fish and Wildlife Service, unpublished data). The underlying cause(s) for sandhill cranes failing to reoccupy much of their historic breeding range in the northern plains, including the PPR, have remained poorly understood.

Hunting is the primary known source of mortality in the MCP (Tacha et al. 1994) and over the past 3 decades, numbers of individuals participating in crane hunting and harvest have increased markedly (Sharp et al. 2007). How these additional pressures may have affected MCP *G. c. tabida* is poorly understood and has increased the need for quantitative information on number and distribution of this subspecies in the MCP. Our primary objectives were to: 1) estimate number of *G. c. tabida* in the MCP, 2) evaluate their current breeding, fall staging, and wintering distributions, and chronology of use of these areas, 3) identify fall and winter use in areas open to sandhill crane hunting, and 4) assess the potential role of crane hunting in determining the breeding distribution of *G. c. tabida* in the northern plains.

STUDY AREA

The capture and marking of sandhill cranes with PTTs occurred in the Central Platte River Valley (CPRV) and North Platte River Valley (NPRV) of south-central Nebraska between 22 February and 12 April 1998-2003 (Fig. 1). The capture and marking with VHF transmitters occurred in the CPRV between 20 February and 10 April 2003-2006. Detailed descriptions of the CPRV (U.S. Fish and Wildlife Service 1981, Krapu et al. 1982) and NPRV (Krapu et al. 1987) have been published previously.

METHODS

Crane Capture and Marking Strategy

G. c. tabida were captured and marked with PTTs and VHF transmitters at sites in the CPRV and NPRV where virtually the entire MCP gathers along the Central Platte and North Platte Rivers in late winter and early spring of each year (Krapu et al. 2011). Capture was in fields, mostly pastures near water, using concealed rocket-propelled nets that were fired over cranes (Wheeler and Lewis 1972) that had been attracted with decoys (taxidermy mounts) within the capture zone of the net. Sandhill cranes begin arriving in the CPRV and NPRV in mid-February, a rapid buildup follows starting in early March, and the population generally peaks in late March (Reinecke and Krapu 1986). We scaled our trapping schedule accordingly by capturing birds throughout the period they were arriving in Nebraska and with trapping effort increasing as the percentage of the MCP present increased. Trapping effort and number of birds captured and marked were distributed approximately proportional to the number of birds using each major section of the river (Krapu et al. 2011). We assumed that subspecies and breeding affiliations of cranes were captured and marked in proportion to their abundance in sections of river. Only 1 individual of a subspecies received a PTT from each successful capture attempt where individuals of more than 1 subspecies were caught. Trapping was conducted in the Chapman to Shelton, Shelton to Kearney, and Kearney to Overton sections of the CPRV, and the Hershey section of the NPRV during spring 1998-2003. *G. c. tabida* receiving PTTs formed a representative sample of this subspecies in the MCP and were used to estimate percentage and number of in the MCP.

To supplement information on geographic distribution of *G. c. tabida* in the MCP throughout the annual cycle, 6 birds were trapped and marked with PTTs in late winter and spring of 2003. Also, fall-staging distribution was obtained for 16 VHF-radioed *G. c. tabida* from a radio-marked sample of the 3 subspecies as part of studies to estimate annual recruitment rates of MCP sandhill cranes during 2003-2006. Trapping and marking of *G. c. tabida* with PTTs in 2003 and VHF transmitters in 2003-2006 occurred in the Chapman to Shelton and Shelton to Kearney sections of the CPRV relying on a representative sample of each group to assess geographic distribution. Restricting marking of cranes to these sections of river was acceptable because satellite telemetry studies during 1998-2002 had indicated in spring that nearly all MCP *G. c. tabida* stage in the Chapman to Kearney reach of the CPRV (G. Krapu, unpublished data).

Upon capture of each crane selected to receive a PTT or a VHF transmitter, a blood sample was drawn from the metatarsal vein to determine sex. The collected blood was placed into a storage/lysis buffer (0.1M Tris, 0.1M EDTA, 5% SDS, 0.01M NaCl, Longmire et al. 1991). Sex was determined using the PCR methods of Duan and Fuerst (2001). The following linear measurements (to the

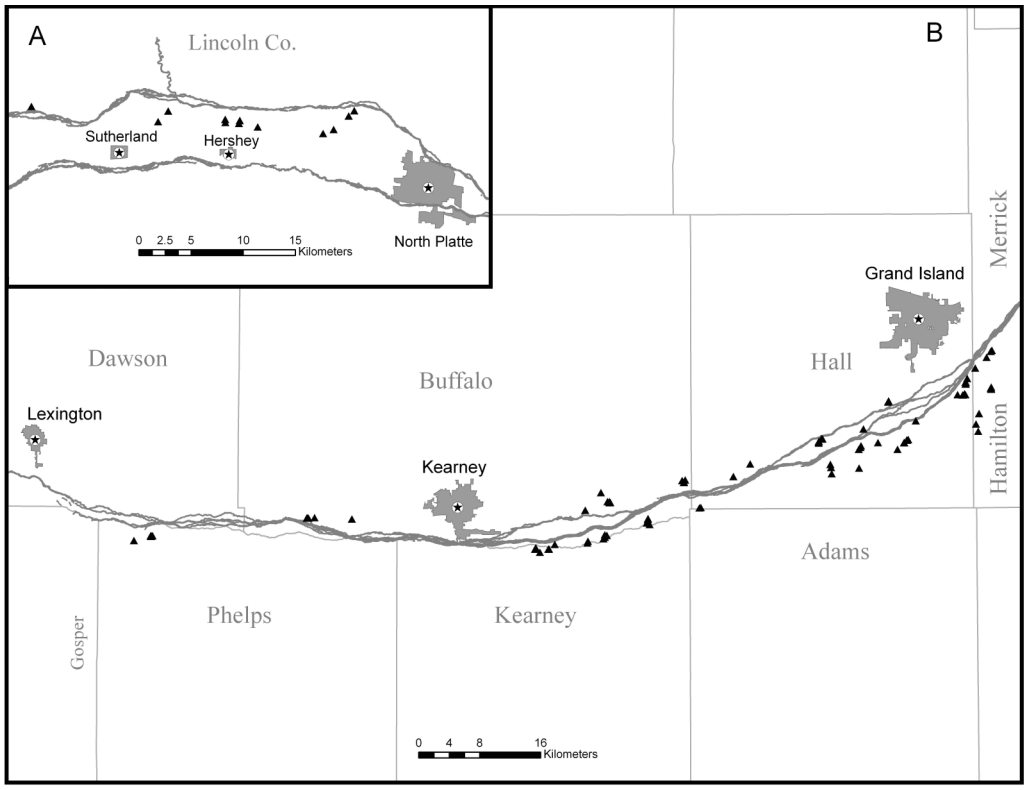

Figure 1. Study areas in (A) North Platte River Valley and (B) Central Platte Valley with sites shown where sandhill cranes were trapped and marked with PTTs and/or VHF transmitters during late winter/early spring of 1998-2006. Virtually the entire mid-continent population of sandhill cranes stages during March in the Central Platte River Valley and North Platte River Valley.

nearest mm) were taken of all captured cranes: wing chord, tarsus, and post-nares culmen. Using these metrics, *G. c. tabida* were distinguished from *G. c. canadensis* and *G. c. rowani* based on morphological differences using the discriminant methods of Johnson and Stewart (1973). In this paper, we report on results only for cranes classified as *G. c. tabida* and *G. c. rowani* based on their morphometry. Each PTT or VHF transmitter was attached to the left leg above the tibio-tarsus using a 2-piece leg band (Ellis et al. 2001). All capture and marking procedures were approved by the Animal Care and Use Committee at the USGS Northern Prairie Wildlife Research Center and conformed to recommendations of the American Ornithologists' Union (1997).

PTT Tracking

Two manufacturers supplied the PTTs used in this study: Microwave Telemetry Inc. of Columbia, Maryland and North Star Science and Technology LLC of Baltimore, Maryland. The Argos satellite system (Service Argos 1996) was utilized to monitor locations of PTT-tagged cranes. The system consists of UHF receivers carried on polar-orbiting National Oceanic and Atmospheric Administration weather satellites which receive PTT transmissions within their field of view. Locations are calculated from the Doppler shift in the received frequency as the satellite passes over the transmitter. Information is transferred to Earth-based processing centers which make the data available to users through personal computers within a few hours of acquisition. Location, date, time, and an accuracy assessment are relayed to processing centers with location information. Data received by Service Argos were obtained via daily e-mail message and were compiled to construct the database used. Fancy et al. (1988) and Harris et al. (1990) provide a more detailed description of the Argos system and its application in tracking wildlife.

PTT Location Data

A final dataset of PTT locations was created from all resolved satellite locations which contained only those which passed through a stepwise sequential geospatial algorithm and subjective manual review. All data were run through the Douglas Argos-Filter Algorithm version 6.5 (http://alaska.usgs.gov/science/biology/spatial/douglas.html) developed by David Douglas (USGS, Anchorage, Alaska) which marks records for deletion that do not pass the user defined criteria for inclusion. The resulting output was then manually scrutinized as a GIS layer and subjective decisions were made as to the legitimacy of removing each individually marked as well as unmarked locations deemed unrealistic or improbable.

During the breeding season (June-August), most cranes were confined to relatively small areas indicating a sedentary period in the annual cycle. To reflect this, a single breeding season ground location for each PTT-monitored crane was created by calculating a weighted mean of all breeding ground locations. Each observation was weighted by a numeric representation of the Argos Location Class (LC 3 = 4, LC 2 = 3, LC 1 = 2, LC 0 = 1) to reflect the decreasing accuracy of these location classes and to theoretically arrive at a more precise activity center estimate.

PTTs were programmed according to 1 of 2 unique duty cycles and transmitted approximately as follows (number of PTTs of each duty cycle referenced hereafter = 7 and 6, respectively): once every 1.5 and 4 days while staging in the CPRV and NPRV after deployment (March), once every 1 and 4 days from approximately when the cranes departed from the CPRV and NPRV to their arrival on the breeding grounds (April through May), once every 4 and 7 days while on the breeding grounds (June through mid-August), once every 1.5 and 4 days during fall migration (mid-August through mid-November), once every 4 and 10 days while at wintering areas (mid-November through January), and once every 3 and 5 days for the duration of the transmissions (North Star PTTs were programmed to shut off during early June after reaching the breeding grounds for the second year). The expected life span of PTTs was projected to be 16 months, which would enable an evaluation of level of philopatry to breeding sites used the previous year.

VHF Location Data

VHF-radioed cranes were relocated by aerial reconnaissance while on fall staging areas in North Dakota, southwestern Manitoba, northwestern Minnesota, and Saskatchewan using pre-selected routes every 5 days during the fall staging periods in 2003-2006. Fall staging location indicated whether the bird had come from a breeding ground in west-central or east-central Canada based on information gained from satellite telemetry during 1998-2003 (Krapu et al. 2011). Aerial surveys began in early September and continued through mid-October to detect arrival of VHF-marked individuals on fall staging areas. When a VHF-radioed bird was detected, its location was relayed to ground crews distributed across major sandhill crane staging areas in Canada (east-central Saskatchewan/southwestern Manitoba, central Saskatchewan, and west-central Saskatchewan), northwestern Minnesota, and North Dakota. We attempted to immediately locate each marked crane via telemetry and obtain a visual observation. Unique radio frequency and the alpha-numeric symbols on the plastic leg band on each crane served to distinguish individuals.

RESULTS

Estimated Abundance

Seven of the 133 (5.3%) cranes from a representative PTT-marked sample of all 3 subspecies were classified as *G. c. tabida* based on their morphological measurements. With 5.3% estimated to be *G. c. tabida* in a spring MCP of 600,000 cranes (Kinzel et al. 2006, Krapu et al. 2011), we estimate the MCP contained 31,579 ± 11,661 (mean ± SE) *G. c. tabida* during 1998-2002.

Breeding Distribution

The 13 PTT-marked *G. c. tabida* spent the breeding season at the following locations: northwestern Minnesota (n = 4), Ontario (n = 2), Manitoba (n = 4, including 2 near the Minnesota border), Alberta (n = 2), and Saskatchewan (n = 1) (Fig. 1). Overall, 8 of the 13 cranes (62%) settled in the transition area between the

temperate prairies and either the mixed woods shield (Minnesota, Manitoba) or boreal plain (Alberta, Saskatchewan) (see Commission for Environmental Cooperation [1997] for descriptions of ecological regions). Ten of 13 (77%) of the PTT-marked cranes spent the breeding season in east-central Canada (Manitoba, Ontario) and Minnesota, and 3 of 13 (23%) settled in west-central Canada (Alberta and Saskatchewan). One *G. c. tabida* was located near the west shore of James Bay along the eastern edge of the Hudson Bay plain, a region inhabited primarily by *G. c. rowani.* Of 16 VHF-radioed cranes relocated on fall staging areas, 11 (69%) and 5 (31%) originated from breeding grounds in east-central Canada and west-central Canada, respectively.

The breeding distribution of *G. c. tabida* overlapped extensively with *G. c. rowani*, particularly in Manitoba and Ontario (Fig. 1). In Minnesota, 4 of 5 cranes that settled in the state during the breeding season were *G. c. tabida* and the remaining bird was a *G. c. rowani*. The 3 *G. c. tabida* that settled in Alberta and Saskatchewan were located along the southern boundary of *G. c. rowani* distribution.

Use of Fall Staging Areas

Average dates of arrival and departure of PTT-marked *G. c. tabida* from fall staging areas were 7 September and 19 October, for an average length of stay of 40 ± 4 (SE) days (Table 1). *G. c. tabida* (PTT-marked sample) spent fall-staging principally in the following states and provinces: northwestern Minnesota (n = 4), eastern North Dakota (n = 2), southwestern Manitoba (n = 3), and eastern and central Saskatchewan (n = 4). The fall staging distribution of VHF-radioed *G. c. tabida* was as follows: eastern and central Saskatchewan (n = 5), southern Manitoba (n = 4), central and eastern North Dakota (n = 6), and northwestern Minnesota (n = 1).

Use of Wintering Grounds

PTTs from 10 of 13 *G. c. tabida* continued to function and were tracked to their wintering grounds in the year of marking and 2 in the second year. Four cranes ultimately settled along the upper Texas Gulf coast and another stayed most of winter along the Gulf coast in the state of Tamaulipas in Mexico (Fig. 3). One bird migrated as far south as the Texas/Oklahoma border, spending the entire winter shifting between areas in Kansas and Oklahoma. Two birds went directly to western Texas and wintered there. Two cranes were monitored during 2 winters and exhibited a different pattern each year, i.e., both stopped in western Texas (Hunting Zone A) during the first year (2002), but after first spending time in Hunting Zone A in the second year (2003), both ultimately moved to the Texas Gulf Coast (Hunting Zone C) (Fig. 2). Two of 3 PTT-marked cranes from Minnesota with transmitters continuing to function during the first winter migrated to the upper Texas Gulf coast. One monitored crane from Minnesota wintered in Zone A during its first winter and on the upper Texas Gulf coast in year 2.

Exposure to Hunting Seasons

Fall Staging in Northern Plains.–Over fall and winter, PTT-marked cranes from breeding sites in Minnesota (n = 3) were exposed to hunting approximately half of the days (26 vs. 55%) compared to cranes from breeding grounds in Alberta, Saskatchewan, Manitoba, and Ontario that staged in North Dakota, Manitoba, and Saskatchewan (n = 8). Within North Dakota, 97% of crane-use days (n = 8) during fall staging occurred within Hunting Zone 1 and 3% within Hunting Zone 2 (n = 3) (Fig. 2).

Post-fall Staging.–Six of 11 PTT-marked *G. c. tabida* (from a total of 13 migrations; 2 birds were tracked during 2 fall migrations) stopped during fall ≥4 days in Kansas. Crane duration of stay ranged from 4 to 23 days (11.8 ± 3.2 days) and the birds were exposed to hunting seasons for 58% of that period. Six of 10 cranes (12 migrations) stopped in Oklahoma with duration of stay ranging from 3 to 70 days (24.5 ± 10.6 days) and the birds were exposed to hunting 73% of the time. Cranes that staged in Minnesota during fall migrated southward through the western part of the state avoiding exposure to hunting seasons until arriving in Kansas and Oklahoma (Fig. 2). After departing the northern plains, exposure rates of cranes to hunting seasons from breeding grounds in Minnesota and all other locations were similar (40 vs. 43%).

Wintering Grounds.–Seven of 10 PTT-marked *G. c. tabida* spent most of their first winter in Texas (9 of 12 migrations), 2 birds reached Texas in 2 winters and one did not use Texas for the majority of winter in year 1. Mean stay by cranes on wintering grounds was 118.9 ± 8.2 days with exposure to hunting seasons during 42% of that

Table 1. Arrival dates, departure dates, length of stay, and number of days 13 PTT-tagged greater sandhill cranes (*G. c. tabida*) were known to be exposed to hunting while on fall staging areas in the northern plains from 1 September through departure. Information in parentheses after crane PTT identification number represents year of migration and location of breeding grounds (BG).

Crane (year)	Arrival date	Depart date	Length of stay	Days exposed to hunting[a]
21428 (2000: BG = West-central Saskatchewan)				
Saskatchewan	1 Sep	15 Oct	45	45
North Dakota	19 Oct	19 Oct	1	1
South Dakota	19 Oct	19 Oct	1	1
13619 (2001: BG = West side of James Bay, Ontario)				
Ontario	1 Sep	6 Sep	6	0
North Dakota	10 Sep	20 Oct	41	28
South Dakota	24 Oct	24 Oct	1	0
13617 (2001: BG = Southeast Manitoba along Minnesota border)				
Minnesota/Manitoba	1 Sep	9 Oct	39	21
North Dakota	9 Oct	22 Oct	14	10
13622 (2002: BG = South-central Alberta)				
Alberta	1 Sep	18 Sep	18	0
Saskatchewan	22 Sep	9 Oct	18	18
North Dakota	13 Oct	13 Oct	1	1
13622 (2003: BG = South-central Alberta)				
Alberta	1 Sep	20 Sep	20	0
Saskatchewan	25 Sep	11 October	17	17
13625 (2002: BG = Northwest Minnesota)				
Minnesota	1 Sep	18 Oct	48	0
13625 (2003: BG = Northwest Minnesota)				
Minnesota	1 Sep	13 Oct	43	0
South Dakota	18 Oct	18 Oct	1	1
21932 (2002: BG = West side, north end of Lake Winnipeg, Manitoba)				
Manitoba (1 day in ND)	1 Sep	7 Oct	37	37
North Dakota	9 Oct	11 Oct	3	3
South Dakota	12 Oct	12 Oct	1	1
13647 (2003: BG = Northwest Minnesota)				
Minnesota	1 Sep	2 Nov	63	0
South Dakota	3 Nov	3 Nov	1	1
13599 (2003: BG = Northwest Minnesota)				
Minnesota	1 Sep	17 Oct	47	0
South Dakota	19 Oct	23 Oct	5	0
13601 (2003: BG = Northeast Manitoba)				
Manitoba	1 Sep	21 Sep	21	18
North Dakota	23 Sep	19 Oct	27	27
South Dakota	21 Oct	21 Oct	1	1
13607 (2003: BG = East-central Alberta)				
Saskatchewan	1 Sep	11 Oct	41	41
North Dakota	12 Oct	12 Oct	1	1
13611 (2003: BG = Southeast Manitoba)				
Manitoba	1 Sep	28 Sep	28	28
Minnesota	28 Sep	28 Sep	1	0
North Dakota	28 Sep	23 Oct	26	24
South Dakota	24 Oct	24 Oct	1	1

[a] Only days and contiguous intervals that cranes were known to be located in areas open to hunting and a season was ongoing are included.

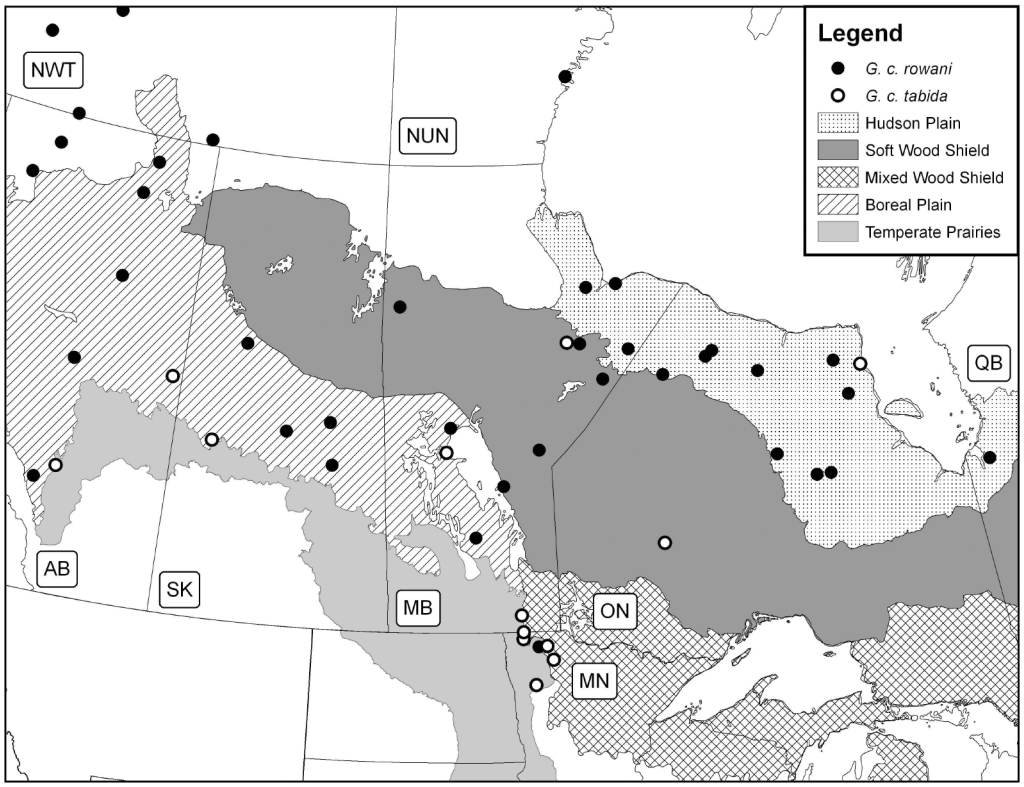

Figure 2. Distribution of PTT-marked *G. c. tabida* (*n* = 13, open circles) and *G. c. rowani* (*n* = 36, closed circles) by ecological region (as defined by Commission for Environmental Cooperation 1997) in central Canada and northwestern Minnesota during the 1998-2003 breeding seasons.

period. Overall, exposure to hunting seasons for all cranes located in Texas (10 birds, 12 migrations) was 41%. Estimated exposure of cranes to hunting seasons varied by management unit in Texas with birds in Hunting Zones A, B, and C being exposed to hunting seasons 62, 22 and 27% of their stay, respectively. One bird made substantial use of the area closed to hunting but moved back and forth between Zone C; all use of Zone C except for 1 day occurred while the hunting season was closed. One crane departed from its fall staging area in Saskatchewan and proceeded almost directly to Tamaulipas spending 6 days in Kansas, and 4 days in Texas before reaching its winter destination. This bird stayed in Tamaulipas for 104 days before returning to the Platte River, Nebraska in spring.

DISCUSSION

Estimated Abundance

Our estimate that *G. c. tabida* account for 5.3% of MCP sandhill cranes is at the upper end of the range of estimates of 1-5% proposed under the Cooperative Management Plan (Central Flyway Council 1981). The small size of the representative sample used to estimate number of *G. c. tabida* in the MCP produces wide 95% confidence limits. Conservatively, using the low end of the confidence limits, *G. c. tabida* accounts for 1.5 % of the MCP.

Breeding Distribution

Numbers of *G. c. tabida* in Minnesota have increased markedly from 1944 and 1977 when an estimated 10-25 pairs (Walkinshaw 1949) and 150-300 pairs (Henderson 1978), respectively, were estimated to be present in the state. The 4 of 13 (31%) PTT-marked birds that formed the sample for Minnesota projects to 9,717 ± 8,247 *G. c. tabida* occurring in the state during the 1998-2003 breeding seasons. Given the small size of our sample of PTT-marked birds, more research is needed to provide a more definitive estimate on numbers of cranes present in Minnesota during the

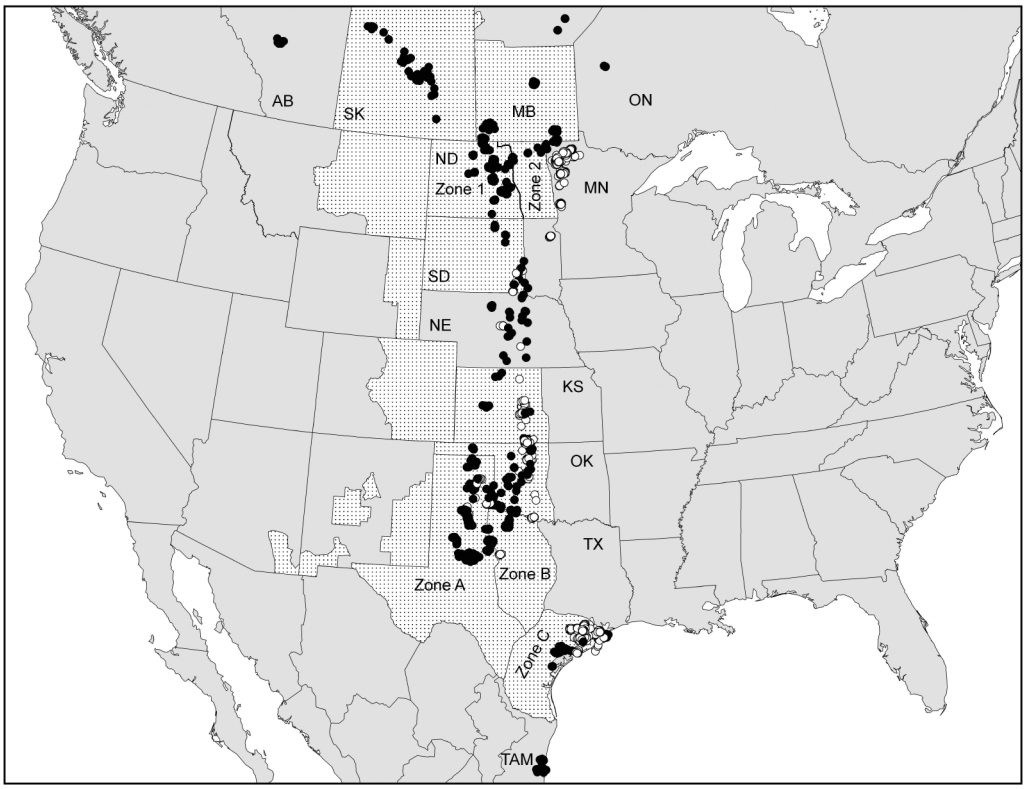

Figure 3. Distribution of locations of PTT-marked *G. c. tabida* (*n* = 11) by hunting zone in North Dakota, Kansas, Oklahoma, and Texas during fall migration and winter. Locations of sandhill cranes from breeding grounds in Alberta, Saskatchewan, Manitoba, and Ontario are represented by closed circles and from Minnesota by open circles.

breeding season. Several other studies also have shown evidence of growth in number of sandhill cranes breeding in Minnesota since 1944 (Johnson 1976, DiMatteo 1992, Provost et al. 1992).

Less than one-third of PTT-marked *G. c. tabida* settled within the temperate prairies ecological region during the breeding season with most being at the edge of this region. This pattern suggests the distribution of this subspecies is now concentrated primarily at the periphery of their historic prairie breeding range in the northern plains. In North Dakota, single sandhill crane breeding records were reported in 1973 (Fields et al. 1974) and 1993 (T. Grant, U.S. Fish and Wildlife Service, unpublished data), along with 2 pairs during 2007 (T. Grant, U.S. Fish and Wildlife Service, unpublished data), which indicate cranes continue to attempt to reoccupy breeding grounds in the state but with little success. The near absence of sandhill cranes from the state's breeding avifauna represents a marked departure from their past status as a plentiful breeder (Coues 1874:533).

Potential Factors Responsible For Current Breeding Distribution

The failure of sandhill cranes to reoccupy their historic breeding range in the northern plains, and particularly North Dakota and South Dakota, while flourishing in northwestern Minnesota, poses a question of cause(s). Sandhill cranes now breed across parts of Indiana, Illinois, and Iowa, where only small remnants of the widespread wetland habitat remain that once supported the species in these states (Meine and Archibald 1996). It appears unlikely that loss of wetland habitat can explain the lack of breeding by sandhill cranes in the PPR as wetland habitat that is likely suitable for breeding remains widespread. In the Dakotas, several major national wildlife refuges, numerous waterfowl production areas, scattered state game management areas, and many privately owned wetlands contain habitat probably suitable for sandhill crane breeding, but cranes seldom nest in these states.

Evidence suggests mortality rates of MCP *G. c. tabida* breeding in Minnesota were lower than elsewhere because these cranes were not subject to harvest until after departure from fall staging areas, in contrast to those that stage in the northern plains. Most documented mortality of cranes in the MCP is from hunting with an estimated 33,000 being shot annually in the United States, Canada, and Mexico (Sharp et al. 2007). In North Dakota, Saskatchewan, and Manitoba, estimated retrieved harvest averaged 4,181, 8,138, and 1,506 sandhill cranes during 2000-2006, respectively (Kruse et al. 2008). *G. c. tabida* and *G. c. rowani* breeding in Saskatchewan, Manitoba, Alberta, and Ontario stage during fall in areas where crane hunting seasons are open during most of their stay based on our findings. In North Dakota, fall-staging *G. c. tabida* accounted for an estimated 60, 28, 35, and 44% of cranes shot by hunters in Benson, Pierce, Sheridan, and Stutsman counties, respectively, during 1990-1994 (Kendall et al. 1997). Distribution of harvest of *G. c. tabida* suggests this subspecies and *G. c. rowani* are being shot in numbers disproportionate to their percentage in the MCP (G. Krapu, unpublished data). High exposure to hunting seasons, a large and disproportionate harvest in the northern plains, and high philopatry rates to breeding sites used in previous years (Krapu et al. 2011) suggest that the high breeding concentration of sandhill cranes in Minnesota is due, in part, to a reduced annual mortality rate.

In the northern plains, exposure of *G. c. tabida* to hunting is highest in Saskatchewan where the season begins on 1 or 2 September with virtually the entire province open to hunting, a 5-crane bag limit and large numbers of hunters participating (Central Flyway Webless Migratory Game Bird Technical Committee [Compiler] 2006). Manitoba accounts for only 15% of the combined estimated retrieved harvest of *G. c. tabida* and *G. c. rowani* from Saskatchewan and Manitoba due, in part, to fewer hunters. In North Dakota, 97% of use by PTT-marked *G. c. tabida* occurred in Hunting Zone 1 where birds were exposed to hunting most of their stay and bag limit is set at 3 birds per day. *G. c. tabida* are at a disproportionate risk from hunting on fall staging areas in the northern plains, except in Minnesota, because they arrive 2-3 weeks earlier than *G. c. canadensis* (Krapu et al. 2011).

Conservation Assessment

Restoring sandhill crane across their historic breeding range in the northern plains would represent a major conservation achievement. The potential exists for the sandhill crane to become a locally common breeding species across the temperate and semi-arid prairies ecological regions, including major parts of the PPR. However, it is unlikely numbers would approach historic levels given the extensive loss of wetland habitat over the past 100 years along with other alterations to the landscape.

Our findings suggest the failure of sandhill cranes to reoccupy most of their historic breeding range in the northern plains over the past 60 years probably is caused, in part, by sufficient harvest to severely limit successful pioneering into this region. A new management strategy for sandhill cranes likely will be required if the species is to be restored as a common breeding bird in the northern plains. A reduction in annual harvest of *G. c. tabida* probably could be achieved while maintaining widespread sport hunting of sandhill cranes in the northern plains. Among potential viable options to increase successful breeding in unoccupied areas containing suitable breeding habitat would be to delay the opening of sandhill crane hunting seasons during fall until after most *G. c. canadensis* have arrived on fall staging areas, i.e., the last week of September (Krapu et al. 2011). This change would shorten the exposure period of *G. c. tabida* to hunting and result in greater mixing with other sandhill crane subspecies before hunting seasons began reducing take of *G. c. tabida*. Previous research has indicated that the harvest of *G. c. tabida* and *G. c. rowani* decline in autumn in most counties in North Dakota after *G. c. canadensis* arrive (Kendall et al. 1997). Another potential option would be to restrict crane hunting primarily to areas where significant numbers of sandhill cranes stage in the northern plains. This step would help to expedite restoration by allowing successful pioneering cranes to repopulate large areas while still maintaining widespread hunting opportunities.

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