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Abstract: The highest losses in the Aransas-Wood Buffalo whooping crane population occur during migration. Conservation and recovery of the endangered whooping crane requires understanding of migration patterns to identify important stopover areas and potential sources of mortality or disturbance. We converted the Cooperative Whooping Crane Tracking Project database, containing more than 3 decades of data on whooping crane sightings, to a geographic information system (GIS) to allow coarse scale spatial analyses of whooping crane migration patterns in the United States portion of the Central Flyway. At this writing, the geodatabase contains point data for 1,981 confirmed whooping crane sightings through the spring migration of 2008. Limitations and appropriate uses of the sighting point data are discussed. We compared the distribution of confirmed whooping crane sightings using a flyway-wide analysis and state-specific analyses. State-specific analyses showed substantial differences in distribution of whooping crane sightings between states, illustrating potential differences in habitat availability between states. However, differences in whooping crane distribution between states are confounded to an undeterminable degree by observer bias, illustrating the need for information on whooping crane migration patterns that is less dependent on the distribution of observers qualified to confirm whooping crane presence.

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The whooping crane (*Grus americana*) is an iconic symbol for endangered species conservation in North America. Shooting and loss of breeding habitat with the conversion of prairies to agriculture were principal causes of historic declines in the species (CWS and USFWS 2007). The Central Flyway population, the only self-sustaining population of whooping cranes, numbered 266 cranes in the winter of 2007-2008. The greatest losses to the Central Flyway whooping crane population occur during migration (Lewis et al. 1992). Losses during migration may reach 60-80% of annual mortality even though the migration period comprises about 9 weeks (17 %) of the year (Lewis et al. 1992, CWS and USFWS 2007).

The U.S. Fish and Wildlife Service initiated the Cooperative Whooping Crane Tracking Project (Tracking Project) in the fall of 1975 to collect information on whooping crane migration patterns and stopover sites during migration. In 1985 we integrated the Tracking Project with the Aransas-Wood Buffalo Population Whooping Crane Contingency Plan (Contingency Plan), to enable swift response when whooping cranes encounter hazards during migration through the Great Plains. Principal contacts from Federal and State agencies in each state in the Central Flyway collect information on whooping crane stopovers during migration. This information is sent to the Tracking Project Coordinator in the Nebraska Field Office, USFWS, Grand Island, Nebraska. The Tracking Project database includes hardcopy files of whooping crane sighting reports and digital data in various formats derived from the reports.

Austin and Richert (2001) summarized information in the Tracking Project database along with site evaluation (habitat) information collected between 1975 and 1999. Stehn and Wassenich (2008) illustrated a 320-km (200-mile)-wide whooping crane migration pathway in the Central Flyway using Tracking Project data through 1999. In the fall of 2007, we converted the U.S. portion of the Tracking Project database to a GIS format (ArcMap 9.2, ArcGIS 9, ESRI, Redlands, CA). Conversion of the Tracking Project database to GIS format enabled flyway wide analyses of whooping crane distribution during migration. The GIS shapefiles illustrating the width of the whooping crane migration corridor are widely used by project proponents and

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Federal and State natural resource agencies to evaluate potential project impacts (e.g., from power line construction and wind energy development), to migrating whooping cranes in the Central Flyway. This paper facilitates analyses and interpretation of output from the Cooperative Whooping Crane Tracking Project Geographic Information System (CWCTP-GIS) by discussing the source and limitations of the whooping crane sighting data and the methods used to convert the Tracking Project database to the CWCTP-GIS.

METHODS

Whooping Crane Sighting Point Data

As required by the Tracking Project protocol, whooping crane sightings are reported to State and Federal agency contacts in each state. The agency contacts verify the sightings when necessary or when possible and send a completed sighting report to the Tracking Project Coordinator in the USFWS Nebraska Field Office. The Tracking Project Coordinator then classifies the sighting as confirmed, probable or unconfirmed based on criteria in the Contingency Plan. “Confirmed” sightings are made by a qualified observer such as a wildlife professional or experienced person expected to be competent in the identification of whooping cranes (e.g., an experienced bird watcher who has observed whooping cranes in the past). A sighting is classified as “probable” when the observer's physical description of the bird is accurate and the location, timing, behavior, and number of birds observed are reasonable. An “unconfirmed” sighting meets some but not all of the requirements of a “probable” sighting. The Tracking Project Coordinator maintains a hard copy file and digital database of all confirmed and probable sighting reports.

To develop the CWCTP-GIS, we selected confirmed sightings from the Tracking Project database to reduce error due to misidentification and to maintain consistency in general database structure between the CWCTP-GIS and the master Tracking Project database. All data fields in the Tracking Project database are also in the spatial CWCTP-GIS.

To effectively manage the confirmed sightings in a GIS, we determined explicit locations for each sighting in decimal degrees. Our method varied depending on the form of location information available for each sighting. Prior to the application of GIS, the Tracking Project Coordinator estimated latitude and longitude of each sighting using 1:250,000 scale wall maps and the location description provided in the sighting report. For this reason, many of the latitude and longitude descriptions in the original Tracking Project database were recorded in degrees and minutes only. Since a majority of the confirmed sighting reports also included a cadastral description (township, range, section), we used GIS to refine the degree-minute locations to a finer scale.

Most states in the Central Flyway have a GIS layer that outlines the Public Land Survey System (PLSS) and includes township, range, and section as attributes in the data layer. For all whooping crane sightings that included cadastral data to the section level or finer, we used the cadastral description to estimate latitude and longitude of sightings. A GIS technician navigated to the given cadastral location in ArcGIS and recorded the latitude and longitude for the approximate center of the section or quarter section. We identified sightings of this type as "CadastralSect," "CadastralQuar," or "CadastralHalf” in the CWCTP-GIS. When cadastral information was not available to at least the section level, we added 00 seconds to the recorded degrees and minutes of latitude and longitude and identified this type of sighting in the CWCTP-GIS as "Historic." When neither cadastral nor historic location information was available for a sighting, the GIS technician used the text description of the sighting location, usually expressed in the record as a distance and direction from a landmark such as a town or road intersection. The technician used available GIS reference layers and the text description of location to estimate a latitude and longitude for the sighting and identified these types of records in the CWCTP-GIS as "Landmark." In very rare cases, the whooping crane observer provided global positioning system (GPS) coordinates with their report. We used the GPS coordinates to describe the sighting location and identified this type of record as "GPS" in the CWCTP-GIS.

After point locations were estimated for each sighting, we crosschecked the spatial data with location descriptions using the spatial join feature in ArcGIS. The sighting location points were joined with the cadastral layer to compare the cadastral description from the Tracking Project database to the placement of the points in the CWCTP-GIS. When we found a discrepancy, we investigated and corrected the inconsistency using physical description information in the database or

hardcopy sighting reports. For sightings where no cadastral information was reported we investigated them individually, crosschecking point locations with the text descriptions of location. When a correction was made, it was noted for later reference in the "Location–Notes" field of the CWCTP-GIS.

Migration Corridor Analysis

Using the CWCTP-GIS, we created a set of migration corridors to show the frequency of sightings by distance from a calculated centerline for the migration. We updated the analysis in May 2009, so the migration corridors are based on 1,981 confirmed whooping crane sightings in the U.S. portion of the Central Flyway through the 2008 spring migration. For the 2009 update, Whooping Crane sightings from Canada were added to the U.S. data during creation of the migration centerline, and the line was ended at Aransas to compensate for distortions that occur in the data as it approaches the U.S. northern and southern border. Before the migration centerline was created, 36 atypical sightings were excluded from the analysis to avoid skewing the path of the migration corridor (T. Stehn, personal communication). These atypical sightings included records from Colorado, Wyoming, Minnesota, Missouri, and the Texas panhandle. We sorted the remaining 1,945 U.S. sightings and 1,660 Canadian sightings north to south using their latitude in decimal degrees. For each sighting in the resulting table, we calculated the average latitude and average longitude for the nearest 89 sightings (i.e., the sighting itself, the 44 north of [above] the sighting, and 44 south of [below] the sighting in the table). The resulting new set of points represents a running average of the whooping crane locations. We used a line to connect the new set of average points to represent the centerline or average migration route. Using ArcGIS, we buffered the line in 8-km (5-mile) increments from 8 to 320 km (5 to 200 miles), creating corridors from 16 to 640 km (10 to 400 miles) wide. We used these 8-km buffers and the sightings database to calculate the cumulative number and cumulative percent of sightings within each buffer.

Once we calculated the cumulative frequency of whooping crane sightings at the flyway level, we repeated the frequency analysis using confirmed whooping crane sightings in each state. We clipped the buffer layer to state boundaries and calculated state-specific cumulative frequency of sightings for each state.

RESULTS

Whooping Crane Sighting Point Data

The CWCTP-GIS contains 1,981 confirmed whooping crane sightings from the U.S. portion of the Central Flyway through the spring migration of 2008 (Fig. 1). Confirmed sightings occurred primarily in the states of Montana (n = 39), North Dakota (n = 442), South Dakota (n = 180), Nebraska (n = 431), Kansas (n = 431), Oklahoma (n = 242), and Texas (n = 114), with incidental sightings in Wyoming (n = 1), Colorado (n = 7), Minnesota (n = 5), and Missouri (n = 2).

The CWCTP-GIS is a spatial database containing all the information in the Tracking Project database, but with the added utility provided by a spatial dataset. The data is

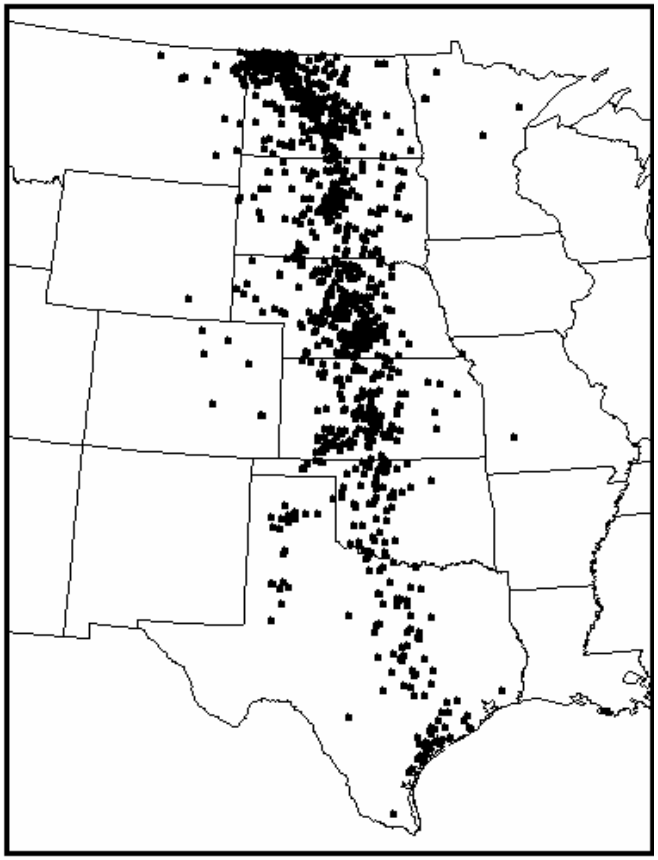

Figure 1. Locations of confirmed whooping crane sightings in the U.S. portion of the Central Flyway through the spring migration of 2008.

stored as a point feature class in an ArcGIS 9.2 personal geodatabase. The Tracking Project Coordinator maintains and seasonally updates the CWCTP-GIS at the USFWS Nebraska Field Office, Grand Island, Nebraska.

Migration Corridor Analysis

The percent frequency of occurrence of whooping crane sightings within various corridor widths (i.e., within various distances from the calculated migration center line) differed between the flyway-wide whooping crane migration corridor analysis and some of the state-specific corridor analyses (Fig. 2). For example, the flyway-wide analysis indicated that approximately 75%, 85%, and 95 % of the confirmed whooping crane sightings in the U.S. portion of the Central Flyway occurred within 48 km, 80 km, and 136 km of the average migration center line (i.e., within a 96-, 160-, and 272-km-wide corridor, respectively). In contrast, the state-specific analysis for Kansas indicates that 75%, 85%, and 95% of the sightings in Kansas occurred within 16, 56, and 112 km of the migration center line (i.e., within a 32-, 112-, and 224-km-wide corridor in Kansas). The state-specific corridor in North Dakota, South Dakota, and Nebraska (to a lesser extent) is wider than the flyway-wide average corridor, whereas the state-specific Kansas and Oklahoma migration corridors are narrower than the flyway-wide corridor (Fig. 3).

DISCUSSION

Whooping Crane Sighting Point Data

Limitations inherent with coarse scale GIS analyses and bias found in any data set of incidental observations influence the use of the CWCTP-GIS. An understanding of the following assumptions and limitations of the data are crucial to correct interpretation of sighting point layers produced using the GIS. Other unknown biases also may exist in the data.

Incidental sightings.–The database is comprised of incidental sightings of whooping cranes during migration. Whooping cranes are largely opportunistic in their use of stopover sites along the Central Flyway, and will use sites with available habitat when weather or diurnal conditions require a break in migration. Because much of the Central Flyway is sparsely populated, only a small percent of cranes stopping

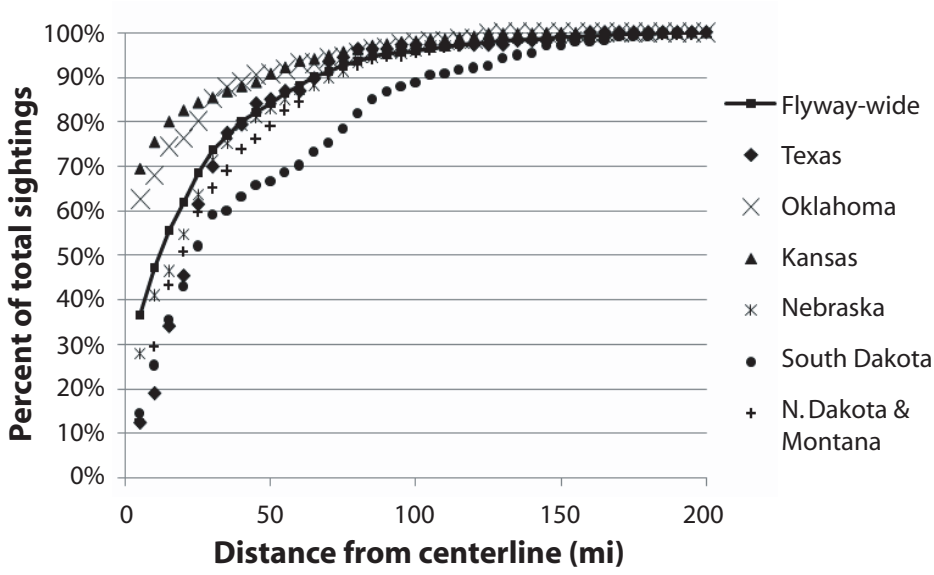

Figure 2. Percent of confirmed whooping crane sightings at various distances from calculated average centerline of the migration corridor based on flyway-wide (solid line) and state-specific analyses of confirmed sightings through spring 2007 in the U.S. portion of the Central Flyway. Total width of migration corridor is equal to twice the distance from centerline. (Slight variations occur in the 2009 version due to the inclusion of fall 2007 and spring 2008 migration data.) 200 miles = 320 km.

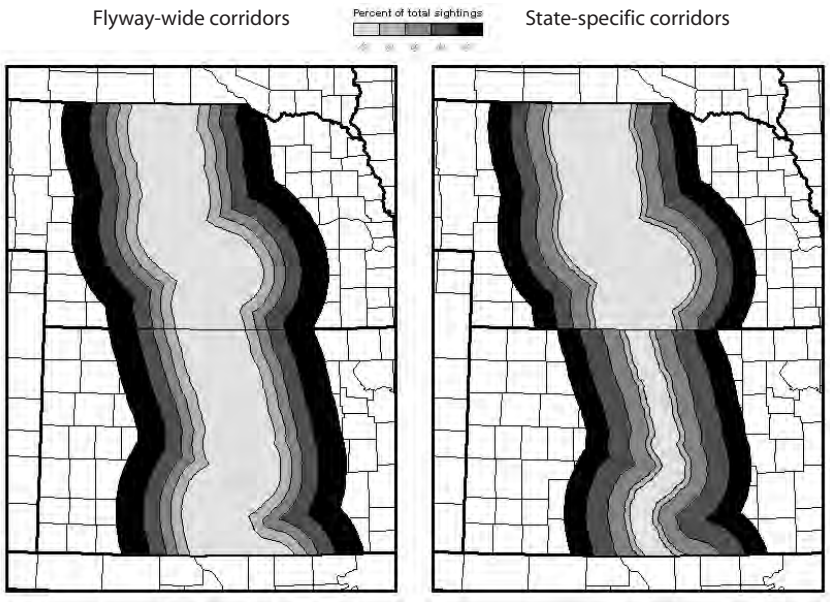

Figure 3. Comparison of whooping crane migration corridors in Nebraska and Kansas using flyway-wide and state-specific analyses of confirmed whooping crane sightings in the Cooperative Whooping Crane Tracking Project Geographic Information System.

during migration are observed. Whooping cranes that are observed may not be identified, those identified may not be reported, and those reported may not be confirmed (only confirmed sightings are included in the GIS database). Based on the crane population levels and average daily flight distances of cranes during migration, as few as 4% of crane stopovers are confirmed annually (T. Stehn, U.S. Fish and Wildlife Service, unpublished data). Therefore, absence of documented use by whooping cranes of a given area in the Central Flyway does not indicate lack of use of that area by whooping cranes or that various projects in the vicinity will not potentially adversely affect the species.

Precision of the data.–An individual sighting is only as precise as the data collected with the sighting. When a "cadastral" location (township, range, section, quarter-section) was provided on the original sighting form, the geographic point representing that sighting in the CWCTP-GIS was placed in the center of the indicated section or quarter-section. These records do not indicate the exact location of the bird in the section. The point representing a "CadastralSect" record would be within 800 m of an actual location of the bird. A "CadastralQuar" record point would be within 200 m of an actual location. In addition, only the first location of the crane group is recorded in the database even though the group may be observed at multiple locations during a stopover. Therefore, the CWCTP-GIS cannot be legitimately used with other available GIS data layers to measure the distance of observed whooping crane groups to various habitat parameters or geographic entities (e.g., wetlands or roads). The CWCTP-GIS is useful for coarse scale analyses of general migration patterns.

Bias.–Bias is an inherent characteristic of any data obtained through incidental sightings. Of the cranes observed and recorded, relatively more sightings are documented in and near areas such as national wildlife refuges where knowledgeable observers are available to look for cranes and confirm their presence. For example, approximately 65% of all confirmed sightings in Oklahoma occur on or within a few miles of Salt Plains National Wildlife Refuge (NWR). Conversely, crane use in many areas may not be documented due to the absence of observers available to confirm the sightings.

Migration Corridor Analysis

The width of migration corridors is narrowed in states such as Kansas and Oklahoma where a high proportion of confirmed sightings are reported at a few areas (e.g., Quivira NWR and Cheyenne Bottoms Wildlife Management Area in Kansas, and Salt Plains NWR in Oklahoma). However, high use by whooping cranes of

areas such as national wildlife refuges is also determined by habitat management at the refuges, and availability of alternative suitable habitat in the region. A relatively small sample size of juvenile whooping cranes marked with radio transmitters in 1981-1983 were followed during subsequent migrations through the spring of 1984 (Howe 1989, Kuyt 1992). Flight paths of the radio-marked cranes were generally more consistent with the wider Kansas and Oklahoma portions of the flyway-wide corridor than the narrower state-specific analysis of the migration corridor in those states. Whooping crane migration corridors based on percent of confirmed sightings should be interpreted conservatively, particularly in Oklahoma and Kansas.

MANAGEMENT IMPLICATIONS

The spatial context of the CWCTP-GIS enables illustration of the whooping crane migration corridor based on frequency of confirmed sightings and promotes broad-scale analyses of whooping crane resources through the Central Flyway. For example, addition of wetland resource shapefiles to the CWCTP-GIS enables analyses of wetland availability throughout the whooping crane migration corridor. As a result, resource agencies can target wetland restoration in the Central Flyway to strategically improve distribution of stopover habitat and provide the greatest benefit to migrating whooping cranes. Additionally, CWCTP-GIS facilitates assessment of cumulative impacts to whooping cranes from various forms of development within their migration corridor in the Central Flyway.

Wind power development and expansion of electric power transmission lines to support the distribution of wind-generated power has increased markedly in the last several years. The wind industry installed 5,249 megawatts (MW) of wind power generation in 2007. By the end of the third quarter in 2008, the total installed capacity was 21,017 MW in 35 states, with over 8,000 MW under construction for completion in 2008 or early 2009 (AWEA 2008). Some of the areas of highest potential for wind energy development lie within the Central Flyway and the whooping crane migration corridor.

Collision with power lines causes the highest known mortality of flighted whooping cranes (Lewis et al. 1992, Stehn and Wassenich 2008). Although whooping cranes migrate well above the height of electric power transmission and distribution lines, the cranes must descend nightly to roost in shallow wetlands (Stehn and Wassenich 2008). The relative probability of whooping cranes migrating through areas targeted for wind energy development and knowledge of the whooping crane habitat availability in areas affected by wind energy development are crucial to the conservation and recovery of the species. CWCTP-GIS point files can highlight areas of documented use but cannot be used alone to determine absence of whooping crane use or whooping crane habitat. Wind development and other projects occurring within the whooping crane migration corridor should be evaluated for effects to migrating whooping cranes and their habitat.

The Tracking Project Coordinator will update the CWCTP-GIS following each migration and distribute the updated sighting location GIS layer to State and Federal cooperators and USFWS Ecological Services Field Offices (ESFO) in the Central Flyway. Migration corridor analyses will be updated as needed and similarly distributed. Contact information for every ESFO can be found on the internet at http://www.fws.gov. Federal regulatory agencies and project proponents should contact their state ESFO for help in evaluating potential project impacts to the endangered whooping crane.

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