M.L. 2014, Chp. 226, Sec. 2, Subd. 05h Project Abstract
For the Period Ending June 30, 2017

PROJECT TITLE: Sandhill Crane Populations and Management in Minnesota
PROJECT MANAGER: David E. Andersen
AFFILIATION: U.S. Geological Survey, MN Cooperative Fish and Wildlife Research Unit, University of Minnesota
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FUNDING SOURCE: Environment and Natural Resources Trust Fund
LEGAL CITATION: M.L. 2014, Chp. 226, Sec. 2, Subd. 05h

APPROPRIATION AMOUNT: $250,000
AMOUNT SPENT: $249,679
AMOUNT REMAINING: $321

Overall Project Outcomes and Results

Sandhill cranes are an important part of Minnesota's natural heritage, and although they have expanded their breeding range in Minnesota, they remain a species of management concern. Minnesota supports two populations of sandhill cranes– the Mid-continent Population that breeds and migrates through northwestern Minnesota, and the Eastern Population that breeds and migrates throughout much of the remainder of the state. We affixed GPS-cell transmitters to 55 sandhill cranes during 2014 and 2015 near the presumed boundary between breeding Mid-Continent and Eastern Population cranes in Minnesota and monitored their seasonal (i.e., migratory) and local movements to (1) determine whether Mid-Continent and Eastern Population cranes breeding in Minnesota overlap in breeding or autumn staging distributions, and if so, identify regions of overlap, (2) quantify habitat-use patterns, especially related to crop depredation, and (3) estimate annual survival rate of Minnesota sandhill cranes:

(1) We identified areas of overlap between breeding populations in northwestern Minnesota, near the historical range boundary of Mid-Continent cranes, suggesting that Eastern Population cranes have expanded their distribution significantly northwest. Furthermore, cranes from both populations used fall staging areas in northwestern Minnesota in the current zone where recreational harvest of Mid-Continent Population cranes was allowed beginning in 2010, indicating at least some overlap of populations during Minnesota's crane hunting season. In addition, some cranes used migration routes associated with both populations, providing potential for population mixing outside of their breeding ranges.

(2) At the local scale, adult and juvenile cranes used crops during both crepuscular and mid-day periods during spring (the peak period of crop depredation), with juvenile cranes exhibiting a stronger preference for crops during crepuscular periods, suggesting that juvenile cranes are more likely to engage in crop depredation than adults. However, juvenile cranes exhibited considerable individual variation in their use of agricultural landscapes.

(3) Finally, our estimates of annual survival rate of Minnesota cranes are consistent with other published estimates of crane survival rate, although because we had difficulty distinguishing mortality from transmitter failure, the uncertainty in our estimates is large.

Our study provides current information about the population affiliation of Minnesota sandhill cranes, and indicates that the recent dramatic growth in abundance of cranes in Minnesota is largely a consequence of an increase in the number and distribution of Eastern Population sandhill cranes in the

state. There is overlap in the distribution of these two populations both on the breeding grounds, and to a lesser extent, during staging, migration, and winter, potentially complicating local management options. Conflicts caused by spring crop depredation are likely disproportionately due to juvenile cranes, and efforts to mitigate crop damage are likely to be most effective if targeted at cranes engaging in depredation, rather than at the entire population through hunting or other means. Generally high annual survival rates likely contribute to a growing Minnesota sandhill crane population, especially Eastern Population cranes.

Project Results Use and Dissemination

We presented our research results via four oral presentations and two poster presentations at professional conferences (the Annual Meeting of the Minnesota Chapter of The Wildlife Society, the Midwest Fish and Wildlife Conference, and the North American Crane Workshop). We presented two invited talks to the Minnesota Department of Natural Resources (the Waterfowl Committee and the Northwest Regional Wildlife meeting). We presented four invited talks in general public scientific settings (Brainerd Lakes Audubon Society, Minnesota Prairie Chicken Society, Maplewood Nature Center, and the Minnesota Waterfowl Association), and a public seminar at the University of Minnesota (Natural Resource Science and Management Graduate Seminar Series). We also gave a presentation to five kindergarten classes in the Mounds View School district. We currently have one manuscript accepted for publication and *in press* at the *Wildlife Society Bulletin*. We also digitally archived the data and programming code required to reproduce the analysis for this publication at the Data Repository for the University of Minnesota, which is part of the University Digital Conservancy. This research project was featured in articles in the following Minnesota newspapers and magazines:

1) Minnesota Study Focuses on Sandhill Cranes. Grand Forks Herald. Brad Dokken. May 17, 2015.
2) Crane Set Record, Prompt Research at Sherburne NWR. Saint Cloud Times. Ann Wessel. November 2, 2015.
3) The Resilience of Sandhill Cranes. Minnesota Conservation Volunteer. Carroll Henderson. March-April edition, 2016.
4) Study's Aim: Shed Light on State's Sandhill Cranes. Outdoor News. Joe Albert. July 22, 2016.

Environment and Natural Resources Trust Fund (ENRTF)
M.L. 2014 Work Plan Final Report

Date of Report: 31 August 2017 (Final Report)

Final Report

Date of Work Plan Approval: 4 June 2014

Project Completion Date: 30 June 2017

Does this submission include an amendment request? No

PROJECT TITLE: Sandhill Crane Populations and Management in Minnesota

Project Manager: David E. Andersen

Organization: U.S. Geological Survey, MN Cooperative Fish and Wildlife Research Unit, University of Minnesota.

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Location: Becker, Beltrami, Cass, Clearwater, Crow Wing, Hubbard, Morrison, Todd, Wadena

Total ENRTF Project Budget:		
	ENRTF Appropriation:	**$250,000**
	Amount Spent:	**$249,679**
	Balance:	**$321**

Legal Citation: M.L. 2014, Chp. 226, Sec. 2, Subd. 05h

Appropriation Language:
$250,000 the second year is from the trust fund to the Board of Regents of the University of Minnesota to delineate population boundaries, habitat use relative to crop depredation, and migration patterns and survival of Minnesota's two populations of sandhill cranes, Mid-continent and Eastern. This appropriation is available until June 30, 2017, by which time the project must be completed and final products delivered.

I. PROJECT TITLE: Sandhill Crane Populations and Management in Minnesota

II. PROJECT STATEMENT

Sandhill cranes (*Antigone canadensis*) are considered to be an important part of Minnesota's natural heritage, and although they have expanded their breeding range in Minnesota, they remain a species of management concern. Minnesota supports two populations of sandhill cranes– the Mid-continent Population that breeds and migrates through northwestern Minnesota, and the Eastern Population that breeds and migrates throughout much of the remainder of the state. Minnesota initiated a sandhill crane hunting season on Mid-continent Population cranes in 2010, and Eastern Population cranes are currently hunted in Kentucky and Tennessee. Several other eastern states are currently considering initiating sandhill crane hunting seasons on Eastern Population cranes, and Mid-continent Population cranes are currently hunted in much of the central U.S. and Canada. Current information on population distribution and migration patterns of sandhill cranes that breed in Minnesota is insufficient for projecting the impact of current and future hunting seasons, and for making informed management decisions in Minnesota. In addition, sandhill crane crop depredation complaints have increased exponentially over the last 10 years in some locations in Minnesota and complaints will likely continue to grow with increasing crane populations. Wildlife managers in the state require a better understanding of crane movements and which cranes (e.g., breeders or non-breeders) are responsible for the damage to address this growing problem.

A 2012 survey estimated there were 7,200 Mid-continent Population sandhill cranes in northwestern Minnesota during the breeding season. How many Eastern Population sandhill cranes breed in Minnesota is not known; recent surveys have tallied approximately 7,500 sandhill cranes staging at Sherburne National Wildlife Refuge during the U.S. Fish and Wildlife Service Cooperative Fall Survey and > 75,000 Eastern Population cranes on fall staging areas across eastern North America. The size of the Eastern Population of sandhill cranes has increased significantly in the past 15-20 years, and Eastern Population sandhill cranes have expanded their breeding range during that period in Minnesota. As crane numbers increase, conflicts between cranes and agriculture will also likely increase, and there will be additional interest in hunting cranes more broadly across Minnesota and the eastern U.S. However, management options in Minnesota are currently limited because the boundary between Mid-continent Population and Eastern Population cranes is not clearly delineated. Furthermore, additional information concerning how and where cranes depredate crops and how cranes use habitat at local and landscape scales is required to effectively manage sandhill cranes in Minnesota. By using GPS-cell transmitters to mark and monitor Eastern Population sandhill cranes in Minnesota we aim to help fill in these important information gaps. Specifically, we propose to address the following goals and objectives:

1. Delineate the boundary between Mid-continent Population and Eastern Population sandhill cranes in Minnesota, allowing these populations to be more effectively managed as separate units.
2. Determine spatial patterns in the use of agricultural crops, grazed and ungrazed grasslands, and wetland habitats by cranes, thereby improving our ability to determine appropriate management actions, including steps necessary to address depredation issues.
3. Evaluate year-round movement patterns (e.g., migration) and survival of Minnesota sandhill cranes.

III. PROJECT STATUS UPDATES:

Project Status as of *31 December 2014*: We captured six sandhill cranes between May and September 2014 and equipped them with GPS/GSM transmitters; three by night-lighting, two by running down pre-fledged colts, and one using a CODA brand Netlauncher. We spent approximately 600 person-hours night-lighting, 350 person-hours finding and chasing down colts, and 280 person-hours using a Netlauncher. To help improve capture efficiency in 2015, we plan to locate nesting cranes using helicopter surveys early in the season and increase the number of employees working on the project.

Project Status as of *31 March 2015***:** In preparation for our 2015 field season, we have arranged for helicopter support to locate breeding cranes early during the breeding season by searching locations in our target capture area with high likelihood of occurrence of breeding cranes, and where access to attempt capture is also likely to

be high. We have prepared to hire and outfit three capture crews to work during periods of low moonlight in April and May, when capture probability is highest. One of those crews will be led by an individual with extensive experience capturing cranes during the breeding season in Illinois and Wisconsin. Following the period when cranes are closely associated with nests and young colts (i.e., April – May), we plan to again capture and attach VHF transmitters to colts, and use subsequent locations of the colt to target capture of adults. Starting in late summer, we also plan to target pairs of cranes for capture using net launchers where we can reliably predict their daily movements. Finally, in the event that we have not yet captured our entire sample of cranes by late summer, we propose to rocket net cranes at concentration areas in central Minnesota (e.g., Sherburne National Wildlife Refuge), based on our observations that marked cranes in 2014 that staged at these locations included cranes that both moved to traditional Eastern Population wintering areas and to wintering areas in southern Texas.

Project Status as of *31 December 2015***:** To increase our capture efficiency, we surveyed for crane nests using a helicopter for approximately 37 hours over two periods in April and May 2015. From April through November 2015, we captured 64 sandhill cranes and equipped 49 of them with GPS/GSM satellite transmitters; we captured 16 by night-lighting, 32 by running down pre-fledged colts (24 of which were equipped with satellite transmitters), and 16 by rocket-netting (six of which were equipped with satellite transmitters). We spent approximately 2,400 person-hours locating roost sites in wetlands and night-lighting, 800 person-hours locating and catching pre-fledged colts, and 150 person-hours rocket-netting.

Project Status as of *31 March 2016***:** We completed Activity 1 (capturing cranes) in November 2015, and we are now focusing our efforts on Activity 2 (monitoring crane movements). We added a live feed of crane relocation data to the website Movebank.org, which is an online repository for wildlife telemetry data. The Movebank website facilitates data storage and export and has resources for annotating animal locations with additional environmental data such as temperature, wind speed, precipitation, etc. We are currently tracking cranes outfitted with GPS-cell transmitters through their spring migrations back to their breeding grounds in Minnesota. We are also analyzing their movement patterns, with initial efforts focused on describing current range boundaries/overlap between MCP and EP cranes.

Status as of *31 December 2016***:** We are currently focusing project efforts on monitoring data feeds of previously captured cranes, analyzing movement data, and writing up results for publication in peer-review scientific journals.

Overall Project Outcomes and Results: Sandhill cranes are an important part of Minnesota's natural heritage, and although they have expanded their breeding range in Minnesota, they remain a species of management concern. Minnesota supports two populations of sandhill cranes– the Mid-continent Population that breeds and migrates through northwestern Minnesota, and the Eastern Population that breeds and migrates throughout much of the remainder of the state. We affixed GPS-cell transmitters to 55 sandhill cranes during 2014 and 2015 near the presumed boundary between breeding Mid-Continent and Eastern Population cranes in Minnesota and monitored their seasonal (i.e., migratory) and local movements to (1) determine whether Mid-Continent and Eastern Population cranes breeding in Minnesota overlap in breeding or autumn staging distributions, and if so, identify regions of overlap, (2) quantify habitat-use patterns, especially related to crop depredation, and (3) estimate annual survival rate of Minnesota sandhill cranes:

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associated with both populations, providing potential for population mixing outside of their breeding ranges.

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Our study provides current information about the population affiliation of Minnesota sandhill cranes, and indicates that the recent dramatic growth in abundance of cranes in Minnesota is largely a consequence of an increase in the number and distribution of Eastern Population sandhill cranes in the state. There is overlap in the distribution of these two populations both on the breeding grounds, and to a lesser extent, during staging, migration, and winter, potentially complicating local management options. Conflicts caused by spring crop depredation are likely disproportionately due to juvenile cranes, and efforts to mitigate crop damage are likely to be most effective if targeted at cranes engaging in depredation, rather than at the entire population through hunting or other means. Generally high annual survival rates likely contribute to a growing Minnesota sandhill crane population, especially Eastern Population cranes.

IV. PROJECT ACTIVITIES AND OUTCOMES:

ACTIVITY 1: Mark 40 sandhill cranes with GPS-cell transmitters in Minnesota

Description: We propose to mark 55 (10 in 2014 and 30 in 2015 plus 15 additional cranes to be marked with cooperator funds prior to receiving Environmental and Natural Resources Trust Fund funding) sandhill cranes along the presumed boundary between Mid-continent Population and Eastern Population cranes in Minnesota with GPS-cell transmitters.

We will capture adult sandhill cranes that are paired during May-August using bait and rocket nets, nest traps, net guns, and/or night-lighting. We will measure morphological characteristics and collect a blood sample for each crane captured and equipped with a transmitter. We will use established procedures to determine sex of captured cranes based on analysis of DNA in blood samples. We will mark all birds captured with a U.S. Geological Survey, Bird Banding Laboratory (BBL) size 8, 1-800, aluminum, butt-end band. We will affix a Cellular Tracking Technologies™ solar-powered GPS transmitter the upper tarsus of the smaller individual of the pair, which is the presumed female.

Summary Budget Information for Activity 1:

ENRTF Budget: $ 157,661
Amount Spent: $ 157,661
Balance: $ 0

Activity Completion Date: August 2015

Outcome	Completion Date	Budget
1. Mark 10 sandhill cranes along presumed boundary in 2014	August 2014	$ 51,163
2. Mark 30 sandhill cranes along boundary in 2015	August 2015	$ 106,498

Activity Status as of *31 December 2014*: We conducted field work from May-September in 2014. We captured six cranes and outfitted them with CTT-1060a model GPS/GSM satellite transmitters designed by Cellular Tracking Technologies specifically for long-legged birds. We banded captured cranes with U.S. Geological Survey, Bird Banding Laboratory aluminum bands, drew blood samples, and took morphological measurements

(mass, length of exposed culmen, total head length, length of tarsus). In an effort to minimize potential stress to captured cranes, we kept handling time to a minimum (mean handling time = 23 minutes, range = 17-30 minutes). We determined sex of captured cranes based on DNA analysis: three captured cranes were females and three were males.

Capture Methodology:

Night-lighting:

We captured three cranes using night-lighting methods, our primary capture approach. We approached suspected crane roost locations on foot using a portable spotlight in tandem with high levels of white noise from mounted speakers on an external-frame backpack. Light from the spotlight helped to find cranes on roosts while also possibly confusing targeted birds to slow their escape. We used white noise to mask the sound of splashing footsteps as the person searched for and approached the cranes.

VHF transmitters with colts:

We captured three colts by chasing them on foot after first locating them foraging in upland habitats and obtaining permission to access the property. We attached a very high frequency (VHF) transmitter to each captured crane colt, allowing the cranes and any nearby roosting adults to be located via radio telemetry during subsequent night-lighting efforts. Later in the season, we attempted to recapture the colt (before fledging occurred in late July) and removed the VHF transmitter. If the parents of the colt hadn't been captured by the time of VHF removal, we had the option of attaching a GPS/GSM transmitter to the colt (we attached two GPS/GSM transmitters to sandhill cranes this way).

Netlauncher:

We captured one crane using a CODA brand Netlauncher under the training and supervision of Dave Fronczak and Tom Cooper (U.S. Fish and Wildlife). We placed small piles of corn in high-use upland areas as an attractant to the cranes. After a sufficient number of days for cranes to acclimate to the bait, we fired a 30' by 30' net at individual cranes when they were within range of the net.

Evaluation of techniques used:

Night-lighting was most effective early in the season when cranes exhibited high daily roost-site fidelity and vegetation had not yet reached heights and densities that negatively influenced our ability to locate roosting cranes at night. The largest obstacle to success with this method was pinpointing the specific locations of roost sites prior to night-lighting efforts. We attempted to increase our efficiency of locating roosting sites by tracking colts with VHF transmitters (colts and adults typically roost together). At times, we experienced electronic interference from the circuitry in the night-lighting backpack unit. Later in the season we incorporated a revised backpack unit that alleviated this issue.

Successful use of the Netlauncher requires spending significant time observing crane behavioral patterns and allowing cranes to acclimate to piles of corn set out as bait. Cranes foraging in upland habitats such as mowed hay fields and pasture often stay in the open to detect potential predators. We deployed the Netlauncher along forest edges to conceal it from cranes, which may have reduced the chance of attracting crane to bait piles. Compared to rocket-netting, the net used with a Netlauncher is much smaller; thus there is a smaller area in which cranes can be captured with each attempt. The main benefit of the Netlauncher is providing capture potential during the day in upland cover that cranes increasingly use later in the summer. We plan to use the Netlauncher again as needed next season.

We considered rocket-netting cranes during the 2014 field season but ended up using a Netlauncher instead. The advantage of rocket-netting over the Netlauncher is a much larger net (allowing a higher success rate of crane capture). Rocket-netting is ideal when cranes forage in consistent spots in high densities. Because our objective for this project was to capture cranes on their breeding grounds (in low densities), the Netlauncher proved to be more appropriate than rocket nets in most situations. David Wolfson was trained in proper usage by a certified trainer from the U.S. Fish and Wildlife Service, and we may consider using rocket-netting in the fall of 2015 when cranes congregate in large numbers and become more attuned to eating waste grain such as corn.

Improvements for the 2015 field season:

The 2015 field season will start a month earlier (in April) to maximize capture efforts during the nesting season when roost locations of incubating cranes are reliable, and we will conduct helicopter surveys to locate cranes and nest locations prior to capture efforts. We will use cartographic modeling to maximize the efficiency of time

spent surveying from the air. As part of that assessment, we will use factors such as presence of emergent vegetation wetlands, distance to roads, land ownership, and on-foot accessibility to identify the areas to search for cranes with the highest likelihood of capture. More field employees will be hired in 2015 to facilitate additional survey crews.

Activity Status as of *31 March 2015***:** We have arranged for helicopter support from the Minnesota Department of Natural Resources, with certification through the Office of Aircraft Services, U.S. Department of Interior. David Wolfson has completed development of a cartographic model to identify target search areas, and helicopter flights are currently scheduled for early to mid-April, depending upon spring phenology. We have identified field crew members and initiated required safety training, arranged field-season housing and vehicle support, and updated necessary permits for capturing cranes in 2015.

Activity Status as of *31 December 2015***:** We conducted field work from 11 April to 4 November 2015. We captured 64 cranes and outfitted 49 of them with CTT-1060a model GPS/GSM satellite transmitters from Cellular Tracking Technologies. We banded all captured cranes with U.S. Geological Survey, Bird Banding Laboratory aluminum bands, drew blood samples, and took morphological measurements. We determined sex of captured cranes based on DNA analysis: 26 of the captured cranes fitted with transmitters were females and 23 were males.

Capture Methodology:

Aerial Surveys:

We flew helicopter surveys on 14 and 16 April 2015, and 28-30 April 2015 for a total of 37 hours of flight time (flight time provided by the Minnesota Department of Natural Resources). We located 45 crane nests throughout the study area and 31 pairs of cranes that we suspected to be breeding pairs, and 60 other observations of single cranes or groups of cranes. We had intended to begin surveying a week earlier to coincide with the first arrival of cranes, but delayed our efforts after finding cranes were initiating nests later than usual due to dry spring conditions. Helicopter surveys allowed us to locate sufficient roosting locations early in the season and helped focus our night-lighting efforts.

Night-lighting:

We captured 16 adult cranes using night-lighting methods. We located 14 of the 16 cranes we captured using night-lighting by tracking colts with VHF transmitters to the roost locations of their parents. Although we found 45 nests during helicopter surveys, some of these nests were on floating vegetation mats that were not safe to access and virtually all of the adult cranes we approached at night in April and May flushed before we could get close enough to capture them. Cranes appeared to be less wary in June and July, allowing us to approach close enough to capture the 14 parents of radio-tagged young.

VHF transmitters and colts:

We captured 32 pre-fledged sandhill crane colts by chasing them on foot. Most of the colt captures occurred in June and early July. We used a smaller model of VHF radio transmitter in 2015 than we used in the 2014 field season. In 2015 we attached Model A2830 glue-on transmitters from Advanced Telemetry Systems to colts. These units weighed 7.5 grams, which is significantly lighter than the transmitters we used on colts in 2014. We sewed the transmitters into a patch of lightweight fabric that had been colored to match the hue of a young crane colt and then glued the patch onto the colt's back between the wings with eyelash glue. Before attaching a transmitter to a colt, we first weighed the colt to make sure the transmitter was < 5% of the mass of the colt. Eyelash glue will only stay attached to the colt for about 2-3 weeks, thus ensuring the VHF transmitter will eventually fall off in the remote chance that we were unable to recapture the colt. This technique had been previously used in Illinois and Wisconsin (Jeff Fox, personal communication) without any deleterious effects on colts. The reduction in mass of transmitters in 2015 allowed us to catch colts substantially earlier in the year (when they were approximately four weeks old versus six-eight weeks old), thus providing a much larger time window to track colts to their roosting parents in wetlands. We recaptured colts once they were approximately eight-nine weeks old (just before fledging occurred) and removed VHF transmitters from them and attached satellite transmitters to 24 of these colts.

Rocket nets:

We captured 16 cranes with two successful fires of a rocket net, and fitted three cranes with transmitters from each capture in an effort to minimize marking cranes belonging to the same family group. We fired rocket nets in private corn and hay fields just north of Sherburne National Wildlife Refuge during mid-October to early November 2015. We patterned daily movements of cranes in the area and obtained permission from local landowners to access private property. We used crane decoys to attract cranes into the capture zone of the rocket net. Sherburne National Wildlife Refuge is a major staging area for cranes in Minnesota, so we are hopeful that these cranes will breed within our study area. Once cranes migrate north in the spring of 2016, we will determine the specific breeding territories of each of these cranes.

Activity Status as of *31 March 2016***:** We have completed our efforts associated with this activity, capturing a total of 72 cranes (*n* = 6 in 2014, *n* = 66 in 2015). We captured 19 cranes by night-lighting, 34 pre-fledged colts by hand, 18 cranes using rocket-nets, and one crane using a Coda NetLauncher. We attached GPS-cell transmitters to 55 (*n* = 24 adults, *n* = 31 colts; *n* = 29 females, *n* = 26 males) of the 72 cranes we captured as part of this study.

Status as of *31 December 2016***:** All fieldwork capturing cranes was completed by November 2015.

Final Report Summary: We captured a total of 72 cranes (*n* = 6 in 2014, *n* = 66 in 2015) during fieldwork from May-September 2014 and April-October 2015. We captured 19 cranes by night-lighting, 34 pre-fledged colts by hand, 18 cranes using rocket-nets, and one crane using a Coda NetLauncher. We attached GPS-cell transmitters to 55 (*n* = 24 adults, *n* = 31 colts; *n* = 29 females, *n* = 26 males; 35 family groups) of the 72 cranes we captured as part of this study. To aid in locating breeding adults, we attached 6.7-gram VHF transmitters to 34 pre-fledged colts (*n*=2 in 2014, *n*=32 in 2015).

Nighlighting was extremely time intensive, requiring time spent gaining property access, locating roost sites of breeding cranes, and in most cases, catching and radio-marking a colt from the family group to more easily locate roost sites where adults could be targeted. We re-captured 31 colts just prior to fledging (approximately 50-60 days old), removed the VHF transmitter, and attached a GPS-cell transmitter. As a result, colts represented a significant proportion of our sample, which provided an excellent opportunity to explore fine-scale movement patterns of pre-breeding cranes and track migratory movements of presumed family groups to achieve primary project objectives.

ACTIVITY 2: Acquire movement and habitat data for transmitter-equipped cranes
Description: Beginning with transmitter deployment in 2014, we propose to acquire high-resolution location data for sandhill cranes breeding in Minnesota, and evaluate local and regional movements and habitat use.

The GPS-cell transmitters will record and save GPS locations several times each day and can be programmed to record locations at different intervals throughout the day and at different times of the year. The data are uploaded using cellular phone technology when the bird is within range of a cellular phone tower. Data can be saved for several weeks if the bird is outside the range of a cell tower. The transmitters will be programed to last for a minimum of two seasons.

We will fit statistical models to the location data to describe seasonal movement and habitat use patterns. In particular, we will compare use and availability of different cover types (agricultural crops, grazed and ungrazed grasslands, wetlands) as an index of habitat selection or preference. We will map migration pathways and fit movement models or movement-based home range estimators (e.g., Brownian Bridges) to summarize local movement patterns.

We will assess land-cover abundance and distribution based on a combination of existing land-cover data (e.g., data available through the MN Department of Natural Resources Data Deli [http://deli.dnr.state.mn.us/], U.S. Department of Agriculture National Agriculture Imagery Program) and local surveys in areas used by transmitter-

equipped sandhill cranes. We will use these data, along with high-resolution movement data derived from marked cranes, to identify patterns in use of agricultural crops by Minnesota sandhill cranes.

Summary Budget Information for Activity 2:

ENRTF Budget: $ 92,339
Amount Spent: $ 92,108
Balance: $ 321

Activity Completion Date: December 2016

Outcome	Completion Date	Budget
1. Acquire high-resolution GPS data for marked cranes	August 2016	$ 28,025
2. Acquire data regarding local habitat (including distribution of agricultural crops)	October 2016	$ 13,760
3. Assess habitat use and patterns of crop depredation	December 2016	$ 50,233

Activity Status as of *31 December 2014*: We began receiving high-resolution location data from captured cranes immediately following their capture. Satellite transmitters were programmed to take locations every 15 minutes throughout daylight hours and to relay the batch of locations via cell phone tower once a day. These data can then be accessed and downloaded in multiple formats at any time from Cellular Tracking Technologies' website. Our data have already revealed valuable life history information including time spent on breeding grounds and the chronology and location of fall staging areas and migration routes. A potentially new or seldom used migration corridor was revealed by a crane captured in northwest Becker County that flew south to eastern Texas (Fig. 3, data through 5 December 2014).

The other cranes captured in 2014 used a more traditional migration strategy that involved staging in western Wisconsin and then continuing on through Illinois and Indiana (Fig. 4, data through 5 December 2014).

We conducted a small side project during fall of 2014 to validate locational accuracy and precision of satellite transmitters not already deployed on cranes. We calculated error rate by using a static control point maintained by the Minnesota Department of Transportation that was surveyed using cadastral methods to an accuracy <3 mm. Fix rate and location accuracy were both very high; 95% of all locations were within 85 m of the true location. We experimentally assigned different fix intervals to each unit to test the accuracy of locations and performance of battery voltage, frequency of data connection, and the association between error rate and horizontal dilution of precision value (HDOP). We plan to use the results of these validation studies to inform future spatial modeling approaches, especially when considering analyses at varying spatial and temporal scales.

Activity Status as of *31 March 2015***:** Since our 31 December 2014 report, we have conducted preliminary review of movement data from cranes marked as part of this project in 2014, including evaluation of step lengths (i.e., distances between successive locations), turn angles, and evaluated seasonal patterns in these statistics. We presented some of these preliminary results at the Joint Minnesota and Wisconsin Chapters of The Wildlife Society Meeting in Duluth, MN in February 2015.

Amendment Request (08/27/2015)
As described in "Activity 1, Improvements for the 2015 field season," we invested additional resources into locating and capturing cranes during the 2015 field season. These activities resulted in increased costs associated with field activities, and we request revision of the approved budget to move funds originally budgeted for transmitters and data services to support crane capture efforts. As part of 2015 field efforts, we used MN DNR funds to support helicopter reconnaissance, which resulted in those funds not being available to support capture efforts in the field. The result of this change is that we will equip fewer cranes with cell transmitters than originally proposed.

Approved by the LCCMR 9-21-2015

Activity Status as of *31 December 2015***:** Nine of the cranes we captured during the 2015 field season migrated to Texas as part of the Mid-Continent Population (Fig. 5, data through 30 November 2015). The remainder of cranes captured during 2015 are currently migrating along routes used by the Eastern Population (Fig. 6, data through 31 December 2015). The map of capture locations shows overlap of the two populations in Becker and Mahnomen counties (the Minnesota Department of Natural Resources Northwest Zone) of the study area (Fig. 7, data through 31 December 2015).

Two of the cranes we captured early in the field season (mid-April) continued north to spend the summer breeding season in Ontario near James Bay. This was unexpected because it was previously thought that migrant cranes had already moved through Minnesota by mid-April.

Because we often used colts to catch adults of the same family group, we ended up with six family groups containing more than one crane with a satellite transmitter. We are unaware of any previous studies that have tracked fine scale movement and migration chronology of cranes within the same family group, so the data from these family groups offer a unique opportunity to learn about synchronization of migration movements and habitat selection within crane family groups during migration.

Research efforts in 2016 will focus on acquiring additional crane relocations and associating these locations with local habitat characteristics, including potential relationships with agricultural areas. We will also begin to analyze crane movement data to evaluate spatial and temporal habitat-selection patterns.

Activity Status as of *15 March 2016***:** We are currently monitoring 34 cranes that are alive and have functional transmitters. Twenty of these cranes are adults and 12 are colts that hatched in 2015 and two are second-year cranes hatched in 2014. There are five family groups in which at least one juvenile and one adult are being monitored.

Wintering Locations

Of the 34 cranes we successfully tracked to overwintering grounds in the winter of 2015-2016 (Fig. 8), 9 cranes migrated to Mid-Continent wintering areas in Texas (*n* = 6), Oklahoma (*n* = 2), and Kansas (*n* = 1). Six of these cranes utilized the traditional migration corridor through the eastern half of the Dakotas, Nebraska, and Kansas. Two cranes migrated east of the traditional corridor by flying through Iowa, Missouri, and Kansas en route to a wintering terminus in Oklahoma. Although exact timing of migration varied among cranes, MCP cranes on average tended to leave breeding territories earlier and spend less time on staging areas than EP cranes.

During the fall and winter of 2015, 25 cranes migrated to Eastern Population wintering areas in Indiana (*n* = 14), Kentucky (*n* = 1), Tennessee (*n* = 5), Alabama (*n* = 3), Louisiana (*n* = 1), and Florida (*n* = 1). Cranes that wintered in traditional EP wintering grounds showed less variability in migration routes (especially between breeding grounds in Minnesota and staging areas in northwest Indiana) than cranes that spent the winter in traditional MCP wintering areas (see Fig. 5 vs. Fig. 6).

Migration routes of cranes from the zone of overlap in the northwest portion of the study area reinforced our finding that the two crane populations are sympatric in parts of Minnesota. In one case two adult cranes from adjacent breeding territories were captured less than a mile from each other and they migrated to different population wintering grounds (Fig. 9). The most unexpected migration route was that of one crane that migrated along the traditional EP migration route all the way to Tennessee before continuing on to the Texas coast. This crane used a traditional MCP migration route along the Plains States in the spring of 2016 to return to its breeding grounds in NW Minnesota (Fig. 10).

Habitat Data

We have obtained spatial habitat data layers that will be used in future analysis. Specifically, we will use the Minnesota Land Cover Classification by Landsat and LiDAR: 2013 update- Version 1 [http://portal.gis.umn.edu/].

This data layer has a 15-m resolution and was made specifically for Minnesota using Landsat and LiDAR data, with funding made available from the Minnesota Environment and Natural Resources Trust Fund (ENRTF). This new data layer has higher resolution and accuracy than the National Land Cover Data 2011 layer, which is frequently used in wildlife analyses.

Amendment Request (10/26/2016)
We have received an invoice from our transmitter vendor for data services that will be incurred between now and the end of the project period (these costs were determined by the number of transmitters that remain functioning and are projected to remain functioning through 30 June 2017, the project end date). We seek permission to adjust our budget to pay these charges using funds currently in the budget lines for Professional/Technical/Service Contracts and Equipment/Tools/Supplies, and use all remaining project funds in those and all other budget lines to support the graduate student working on this project through the end of the project period. Supporting the graduate student working on this project for the remainder of the project period will allow us to complete data analysis and final report and manuscript preparation.

Budget requests:

- Move $4,025 from Equipment/Tools/Supplies (GPS-cell or PTT satellite transmitters) to Professional/Technical/Service Contracts to cover remaining data costs
- Move the remaining $6,145 unspent funds in GPS-cell or PTT satellite transmitters to MS Student Support
- Move $1,117 from Technician salaries to M.S. Student Support
- Move the remaining $2,243 unspent funds in Bands, capture equipment, and miscellaneous field supplies to MS Student Support
- Move the remaining $846 unspent funds in 4-wheel drive vehicle to MS Student Support
- In total, move $10,351 to MS Student Support and $4,025 to Professional/Technical/Services from Equipment/Tools/Supplies ($12,413), Travel expenses in Minnesota ($846), and Technician salaries ($1,117)

Approved by the LCCMR 11-17-2016

Status as of *31 December 2016***:** We are currently monitoring 30 cranes with functional transmitters, 18 adults and 12 colts. Eleven of the colts hatched during the summer of 2015 and one hatched during the summer of 2014. We are currently monitoring four family groups containing ≥ 1adult crane and one juvenile offspring. At the time of writing (December 2016), cranes are actively migrating south for the winter, although the majority of birds has not yet completed their migration.

In addition to monitoring migratory routes to classify population affiliation, we have been using net-squared displacement and variograms to characterize movement trajectories of juvenile and adult cranes during the spring and summer period. During the period from March-July 2016, adult cranes left the wintering grounds earlier, took less time to migrate, and upon arriving in Minnesota immediately returned to their former breeding territory and settled there for the summer. Juveniles migrated later, spent more time migrating, and once in Minnesota exhibited long-distance nomadic movements from April-June. We believe these movements may indicate juveniles are scouting potential future breeding territories (i.e., prospecting).

Final Report Summary: We were unable to assign population affiliation to 14 (28%) cranes due to transmitter failure or potential mortality prior to the first winter. Of 36 cranes (21 adults, 15 juvenile, aka colts) observed for ≥1 winter, we classified 9 as MCP cranes and 23 as EP cranes based on their sole use of either the Central or Mississippi Flyway during migration; population affiliation was ambiguous for 4 cranes that used multiple flyways to migrate between breeding and wintering grounds. Two cranes used the Mississippi (EP) Flyway for fall and spring migrations in fall of 2015 and spring of 2016, but switched to the Central (MCP) Flyway during the fall of 2016. One crane used the Mississippi Flyway in the fall of 2015, continued to Texas to spend the winter in

MCP range, then used the Central Flyway to migrate north in the spring of 2016 (Fig. 10). One crane migrated to Florida, USA, in December 2016 before continuing west to settle for the remainder of the winter on the Texas Gulf Coast. Based on population assignment derived from migratory movements of marked cranes, we estimated that the current range boundary between MCP and EP cranes in Minnesota is near the historical range boundary of MCP cranes in northwestern Minnesota (Fig. 11), suggesting that the EP breeding distribution in Minnesota has expanded considerably northwest.

The degree of plasticity in migratory flyway use among individuals was unexpected, and would not have been possible to document without the use of GPS/GSM satellite transmitters, which allowed us to track individuals remotely and with a high degree of precision. In addition to individual cranes that used multiple migration flyways, we documented several other instances of "unconventional" sandhill crane movements. For example, we observed a third-year crane crossing Lake Michigan on its second spring migration north. It flew parallel to the Michigan shoreline for approximately two hours, covering about 50 miles between Saugatuck and Muskegon, and then flew directly across the lake towards Sheboygan on the Wisconsin side, a flight of about 75 miles that took two hours to complete (Fig. 12). This type of migration over water is probably quite uncommon, as sandhill cranes utilize thermal uplifts during migration to save energy and maximize flight efficiency. Another third-year crane settled in southern Michigan during the summer of 2017, over 600 miles from its natal territory in northern Minnesota. Breeding adult cranes are known to have high site fidelity to breeding territories; however, less is known concerning the annual site fidelity of cranes that have not reached breeding age. Although we only documented one occasion of such a long-distance relocation, it suggests juvenile cranes may settle far from their natal areas, and may serve as agents of population dispersal.

We evaluated crane habitat selection in Minnesota by comparing used habitat with randomly sampled ("available") locations drawn from within individual crane home ranges. We limited our analyses to 1 April-30 June 2016 because the majority of crop depredation occurs in the spring shortly after crops are seeded in the ground. We extracted all locations during the crepuscular periods of dawn and dusk (6-9AM and 6-8PM) and mid-day (10AM-5PM) because cranes typically forage early in the morning and late in the evening and spend a large portion during the middle of the day loafing (i.e., not actively feeding). We summarized habitat use via 93,000 GPS-telemetry locations from 28 cranes (33,000 locations during crepuscular times and 58,000 locations during mid-day) and available habitat using 5,000 points randomly sampled from within a minimum convex polygon representing the home range of each individual crane (140,000 sampled points for each period). We summarized distributions of used and available points separately for adults and juveniles to account for differences in behavior that may influence habitat use (i.e., breeding cranes defend a territory, incubate eggs, etc., whereas juvenile cranes don't have these requirements).

We used the 2016 Cropscape layer from the National Agricultural Statistics Service because it was the most accurate spatial data on crop distributions for Minnesota. We only used the five most common crop types (corn, soybeans, wheat, alfalfa, other hay/non-alfalfa) along with a non-crop category because together these represented > 98% of all crane locations.

Adult and juvenile cranes showed a preference for crops during both crepuscular and mid-day periods (i.e., a higher proportion of available, relative to used, locations fell within non-crop layers; Fig. 13). Adults showed similar use/availability ratios for the two different periods, whereas juvenile cranes exhibited higher use of crops during crepuscular periods. Juveniles also had higher proportional use of crops (particularly corn and soybeans) than adults, suggesting that juvenile cranes were more likely to depredate crops. There was considerable individual variation among both juvenile and adult cranes in their use of habitat, suggesting that a small portion of cranes might be responsible for the majority of crop depredation.

Finally, we estimated juvenile and adult survival rates using the Mayfield estimator, assuming a constant hazard rate over time:

$$\hat{s} = \left(1 - \frac{number\ of\ deaths}{number\ of\ exposure\ days}\right)^{365}$$

We assumed that a localized cluster of locations, followed by a lost signal, was indicative of a mortality event. In most cases, however, it was not possible to determine whether lost signals were the result of transmitter failure or a mortality event. Therefore, to bracket the range of likely survival rates, we generated estimates under 2 extreme assumptions: 1) all lost signals occurred because of a mortality event; 2) all lost signals resulted from transmitter failures (Table 1). The range of survival estimates is quite broad, and for adult cranes encompasses estimates from other studies (e.g., 0.95, 95% CI = 0.86, 0.98 from a recent study of EP cranes).

V. DISSEMINATION:

Description: Results will be summarized in a Master of Science thesis and peer-reviewed publications. One or more presentations will be given at appropriate professional conferences (e.g., The Wildlife Society's Annual Meeting, Minnesota Chapter of The Wildlife Society Annual Meeting). We also propose to make crane location data available via a website accessible to the general public once location data begin to be collected as part of this project.

Status as of *31 December 2014*: David Wolfson gave an invited talk to approximately 50 people in late September 2014 at the Brainerd Lakes Audubon Society in Brainerd, Minnesota. The presentation gave an overview of the ongoing research efforts in Minnesota and provided public outreach. We have also submitted an abstract to present our preliminary results at the 2015 Joint Meeting of the Minnesota and Wisconsin Chapters of The Wildlife Society in February 2015.

Status as of *31 March 2015***:** We submitted and made the following presentation at the Joint Minnesota and Wisconsin Chapters of The Wildlife Society Meeting in Duluth, MN in February 2015:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2015. Spatial ecology of sandhill crane populations in Minnesota. Joint Meeting of the Minnesota and Wisconsin Chapters of The Wildlife Society. Duluth, Minnesota.

Status as of *31 December 2015***:** David Wolfson gave a presentation on this research project to the Natural Resource Science and Management (NRSM) graduate program at the University of Minnesota on 9 December 2015.

Status as of *15 March 2016***:**

We submitted and made the following poster presentation at the 76th Midwest Fish~~eries~~ and Wildlife Conference in January 2016 in Grand Rapids, Michigan:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2016. Spatial ecology of sandhill crane populations in Minnesota. Midwest Fish and Wildlife Conference. Grand Rapids, Michigan.

We submitted and made the following poster presentation at the Minnesota Chapter of The Wildlife Society Annual Meeting in Mankato, MN in February 2016:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2016. Spatial ecology of sandhill crane populations in Minnesota. Minnesota Chapter of The Wildlife Society. Mankato, Minnesota.

David Wolfson gave an invited talk at the Maplewood Nature Center in Maplewood, Minnesota on 2 April 2016 summarizing the research project and providing outreach to the local community.

David Wolfson gave an invited talk at the Minnesota Prairie Chicken Society Annual Meeting in Fertile, Minnesota on 16 April 2016:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2016. Minnesota sandhill crane population affiliation and migration ecology. Minnesota Prairie Chicken Society Annual Meeting. Fertile, Minnesota.

We submitted a manuscript for publication in the peer-reviewed journal Wildlife Society Bulletin on 4 August 2016:

Wolfson, D., J. Fieberg , T. Cooper, J. Lawrence, and D.E. Andersen. Range Overlap between Mid-Continent and Eastern Sandhill Cranes revealed by GPS-tracking. *In revision*.

David Wolfson gave an invited talk at the Northwest Regional Wildlife Meeting of the Minnesota Department of Natural Resources in Thief River Falls, Minnesota on 7 September 2016:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2016. Minnesota sandhill crane population affiliation and migration ecology. Minnesota Department of Natural Resources, Northwest Regional Wildlife Meeting, Thief River Falls, Minnesota.

David Wolfson and John Fieberg gave a presentation to five kindergarten classes at Pike Lake Elementary school in New Brighton, Minnesota on May 21, 2016.

Status as of *31 December 2016***:**

We made the following presentation at the 77th Midwest Fish and Wildlife Conference in February 2017 in Lincoln, Nebraska:

Wolfson, D., D.E. Andersen, T. Cooper, J. Lawrence, and J. Fieberg. 2016. Range overlap between Mid-Continent and Eastern sandhill cranes revealed by GPS-tracking. Midwest Fish and Wildlife Conference. Lincoln, Nebraska.

We made an oral presentation at the 14th North American Crane Workshop in Chattanooga, Tennessee in January 2017:

Wolfson, D., J. Fieberg , T. Cooper, J. Lawrence, and D.E. Andersen. A comparison of movements between adult and juvenile sandhill cranes during spring and summer: evidence for prospecting? 14th North American Crane Workshop, Chattanooga, Tennessee.

We made an oral presentation at the Minnesota Chapter of The Wildlife Society Annual Meeting in Callaway, Minnesota in February 2017:

Wolfson, D., J. Fieberg , T. Cooper, J. Lawrence, and D.E. Andersen. When worlds collide: a current assessment of two formerly distinct sandhill crane populations in Minnesota. 2017 Annual Meeting of the Minnesota Chapter of The Wildlife Society, Callaway, Minnesota.

Final Report Summary:
We presented our research results via four oral presentations and two poster presentations at professional conferences (the Annual Meeting of the Minnesota Chapter of The Wildlife Society, the Midwest Fish and Wildlife Conference, and the North American Crane Workshop). We presented two invited talks to the Minnesota Department of Natural Resources (the Waterfowl Committee and the Northwest Regional Wildlife

meeting). We presented four invited talks in general public scientific settings (Brainerd Lakes Audubon Society, Minnesota Prairie Chicken Society, Maplewood Nature Center, and the Minnesota Waterfowl Association), and a public seminar at the University of Minnesota (Natural Resource Science and Management Graduate Seminar Series). We also gave a presentation to five kindergarten classes in the Mounds View School district. This research project was featured in articles in the following Minnesota newspapers and magazines:

1) Minnesota Study Focuses on Sandhill Cranes. Grand Forks Herald. Brad Dokken. 17 May 2015.
2) Crane Set Record, Prompt Research at Sherburne NWR. Saint Cloud Times. Ann Wessel. 2 November 2015.
3) The Resilience of Sandhill Cranes. Minnesota Conservation Volunteer. Carroll Henderson. March-April edition, 2016.
4) Study's Aim: Shed Light on State's Sandhill Cranes. Outdoor News. Joe Albert. 22 July 2016.

We currently have one manuscript accepted for publication and *in press* at the *Wildlife Society Bulletin*:

Wolfson, David W; Fieberg, John R; Lawrence, Jeff S; Cooper, Tom R; Andersen, David E. *In Press*. Range overlap between Mid-Continent and Eastern sandhill cranes revealed by GPS-tracking. *Wildlife Society Bulletin*.

We also digitally archived the data and programming code required to reproduce the analysis for this publication at the Data Repository for the University of Minnesota, which is part of the University Digital Conservancy:

Wolfson, D. W, J.R.Fieberg, J.S. Lawrence, T.R. Cooper, and D.E. Andersen. 2017. Data, R code, and output supporting: Range overlap between Mid-Continent and Eastern sandhill cranes revealed by GPS-tracking. Retrieved from the Data Repository for the University of Minnesota, https://doi.org/10.13020/D64P42.

We are currently in the process of preparing a second manuscript for publication in the peer-reviewed, scientific literature focused on movements of juvenile cranes and the graduate student on this project (David Wolfson) is preparing his M.S. thesis.

VI. PROJECT BUDGET SUMMARY:

A. ENRTF Budget Overview:

Budget Category	$ Amount	Explanation
Personnel:	$ 113,515	Co-PI salary, M.S. student, technicians
Professional/Technical/Service Contracts:	$ 28,025	Telemetry data retrieval
Equipment/Tools/Supplies:	$ 94,087	Telemetry devices, capture supplies
Travel Expenses in MN:	$ 14,052	Vehicle mileage, lodging, food
TOTAL ENRTF BUDGET:	**$ 249,679**	

Explanation of Use of Classified Staff: N/A

Explanation of Capital Expenditures Greater Than $5,000: N/A

Number of Full-time Equivalents (FTE) Directly Funded with this ENRTF Appropriation: 1.167

Number of Full-time Equivalents (FTE) Estimated to Be Funded through Contracts with this ENRTF Appropriation: N/A

B. Other Funds:

Source of Funds	$ Amount Proposed	$ Amount Spent	Use of Other Funds
Non-state			
MN CFWRU	$ 30,000	$ 43,042	Technician salary, transmitters, supplies
U.S. Geological Survey	*$ 33,222*	*tracked jointly, see "Federal funds"*	Technician salary, travel, transmitters, supplies, overhead
U.S. Fish and Wildlife Service	*$ 51,170*	*tracked jointly see "Federal funds"*	Technician salary, travel, transmitters, supplies, data fees, overhead
Federal funds (USFWS and USGS) are combined into a single agreement and tracked jointly	$ 84,392	$ 84,392	Technician salary, travel, transmitters, supplies, data fees, overhead
State			
MN DNR	$ 25,000	$ 25,831	Aviation support
TOTAL OTHER FUNDS:	**$ 139,392**	**$ 153,265**	

VII. PROJECT STRATEGY:

A. Project Partners:

This project will be conducted cooperatively through the Minnesota Cooperative Fish and Wildlife Research Unit at the University of Minnesota. Project partners include University of Minnesota principal investigators, Minnesota Department of Natural Resources scientists, and U.S. Fish and Wildlife Service biologists. Funds received from this Environmental and Natural Resources Trust Fund request will be received by the University of Minnesota in an agreement with Drs. Andersen and Fieberg as co-Principal Investigators. Funds contributed from other sources will be used to initiate the project prior to Environmental and Natural Resources Trust Fund funds becoming available in 2014.

David Andersen is Leader of the U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit and Adjunct Professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota. Dr. Andersen has considerable experience conducting field studies of birds, including a current project with Eastern Population sandhill cranes. John Fieberg is an Assistant Professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota. Dr. Fieberg is a quantitative ecologist with experience developing analytical approaches for interpretation of animal movement data. Tom Cooper is the Eastern Webless Migratory Game Bird Biologist for the U.S. Fish and Wildlife Service and an Adjunct Assistant Professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota. Dr. Cooper has considerable expertise involving sandhill crane management and biology. Jeff Lawrence is Group Leader of the Wetlands Wildlife and Populations Research Group of the Minnesota Department of Natural Resources, and adjunct Assistant Professor in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota. Dr. Lawrence has considerable experience with management of migratory birds, and currently coordinates breeding surveys of Mid-continent Population sandhill cranes in Minnesota. David Fronczak is a Wildlife Biologist with U.S. Fish and Wildlife Service, Migratory Bird Management. He recently completed an M.S. at the University of Minnesota at the Minnesota Cooperative Fish and Wildlife Research Unit, where his research focused on Eastern Population sandhill crane migration. Mr. Fronczak has considerable experience trapping and attaching satellite transmitters to sandhill cranes.

Project Partners Not Receiving Funds:

- David E. Andersen, U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota. Dr. Andersen will serve as Project Manager, co-advisor for an M.S. student

who will work on the project, and assist in conducting the project. LCCMR funds granted for this project will be administered by the University of Minnesota.

- Jeff S. Lawrence, Minnesota Department of Natural Resources. Dr. Lawrence will assist in conducting the project and serve as liasion with Minnesota Department of Natural Resources staff who will assist with identifying potential study areas.
- Tom Cooper, U.S. Fish and Wildlife Service, Webless Migratory Bird Coordinator. Dr. Cooper will assist in conducting the project and serve as liasion with the U.S. Fish and Wildlife Service, which has management responsibilty for migratory birds.
- Dave Fronczak, U.S. Fish and Wildlife Service. Mr. Fronczak has considerable experience capturing and marking sandhill cranes, and will aid in capture and marking cranes in this project.

Project Partners Receiving Funds:

- John Fieberg, University of MN, Department of Fisheries, Wildlife, and Conservation Biology: 1 month summer salary per year x 2 years, 19.83% fringe benefits - $21,435. Dr. Fieberg will serve as co-advisor for an M.S. student who will work on the project and be involved in project design and execution.

B. Project Impact and Long-term Strategy: Mid-continent Population sandhill cranes are hunted in much of the Central Flyway, and recent data on distribution and abundance of Mid-continent Population cranes is being used to revise existing harvest management strategies. There is considerable management interest in Mid-continent Population cranes that breed and migrate through northwest Minnesota, but relatively little is known about their movement patterns and survival. Recently, the Minnesota Department of Natural Resources implemented aerial, spring surveys to provide better information about Mid-continent Population cranes breeding in Minnesota (J. Lawrence, Minnesota Department of Natural Resources, unpublished report), and tissue samples from Mid-continent Population cranes harvested in northwest Minnesota and adjacent southern Manitoba are being analyzed to derive breeding origins of harvested cranes (G. Knutson, U.S. Fish and Wildlife Service, personal communication). Information derived from the study we are undertaking will help inform harvest management strategies for Mid-continent Population cranes by elucidating the extent and movement patterns of Mid-continent Population cranes that breed in Minnesota.

Eastern Population cranes are currently hunted in the Mississippi Flyway in Tennessee and Kentucky, under a flyway harvest management plan. Other states in the Eastern Population range, including states where Eastern Population cranes breed (e.g., Michigan, Wisconsin, and Minnesota) may also allow hunting of Eastern Population cranes in the future. The work conducted by D. Fronczak as part of his M.S. program at the University of Minnesota addressed how Eastern Population cranes move to and from staging and wintering areas, but high-resolution information about habitat use during the breeding season was not a part of that study. The study we are undertaking will provide high-resolution data on habitat use throughout the year for a portion of the Eastern Population that breeds in Minnesota, and also provide additional data on movement patterns of Eastern Population cranes throughout the year. We also anticipate adding to the relative paucity of data regarding survival of adult Eastern Population sandhill cranes, which can be incorporated into population models that inform management.

Moreover, Minnesota is one of only a few states with >1 population of sandhill cranes breeding within its borders, and both populations of cranes that breed in Minnesota are hunted. Information about how these two populations are distributed across the landscape in Minnesota will help inform crane management in the state. Finally, as the size of the Eastern Population of sandhill cranes has increased, conflicts with agriculture have increased and there are currently approximately 2,000 take permits issued by the U.S. Fish and Wildlife Service to help manage crop depredation by cranes. Our study has the potential to provide additional information about how, where, and when Eastern Population sandhill cranes engage in crop depredation, which in turn could help inform future mitigation policy.

In summary, we are aware of three projects that have obvious and direct connections to the work we are undertaking. First, the Minnesota Department of Natural Resources (J. Lawrence, personal communication) has been conducting spring breeding surveys of Mid-continent Population sandhill cranes in northwest Minnesota, with the objective of monitoring the breeding population in that portion of the state and quantifying abundance and distribution. Our project will compliment that effort by providing more detailed information about Mid-continent Population and Eastern Population cranes that breeding in Minnesota, with special emphasis on the eastern boundary of the Mid-continent Population.

Second, a recently completed satellite telemetry study of Eastern Poplation sandhill crane migration behavior (D. Fronczak, U.S. Fish and Wildlife Service, personal communication) has provided information about movement patterns of Eastern Population cranes between breeding areas and staging and wintering areas. Our project will add to the results of that study by providing migration data on additional Eastern Population sandhill cranes, and will also provide high resolution data regarding habitat use during the breeding season in Minnesota.

Finally, a study of stable isotopes in cranes harvested in northwest Minnesota and adjacent southern Manitoba (G. Knutson, U.S. Fish and Wildlife Service, personal communication) is near completion and is attempting to determine the origin of cranes harvested in northwest Minnesota. Our study will provide high-resolution data regarding where Mid-continent Population cranes that breed in Minnesota occur during the period when they are vulnerable to harvest, which will provide a means of comparison to derivations resulting from isotope analyses.

We expect to be able to meet project objectives during the proposed project period (July 2014 – December 2016) with requested and collaborator funds, and do not anticipate making additional requests to the Environmental and Natural Resources Trust Fund to support this project. We have funds secured and pending to begin this project prior to when Environmental and Natural Resources Trust Fund funds would become available in 2014.

C. Spending History:

Funding Source	**M.L. 2013 or FY14**
MN Cooperative Fish and Wildlife Research Unit	$ 20,000
U.S. Geological Survey	$ 20,000
MN DNR	$ 0
These are estimates based upon available funding and the need to hire crews, purchase transmitters, and begin capturing cranes prior to 1 July 2014	

VIII. ACQUISITION/RESTORATION LIST: N/A

IX. VISUAL ELEMENT or MAP(S): See attached figures.

X. ACQUISITION/RESTORATION REQUIREMENTS WORKSHEET: N/A

XI. RESEARCH ADDENDUM: N/A

XII. REPORTING REQUIREMENTS:
Periodic work plan status update reports will be submitted no later than 31 December 2014, 15 March 2015, 31 December 2015, 15 March 2016, and 31 December 2016. A final report and associated products will be submitted between June 30 and August 15, 2017 (final report scheduled for 31 December 2016)

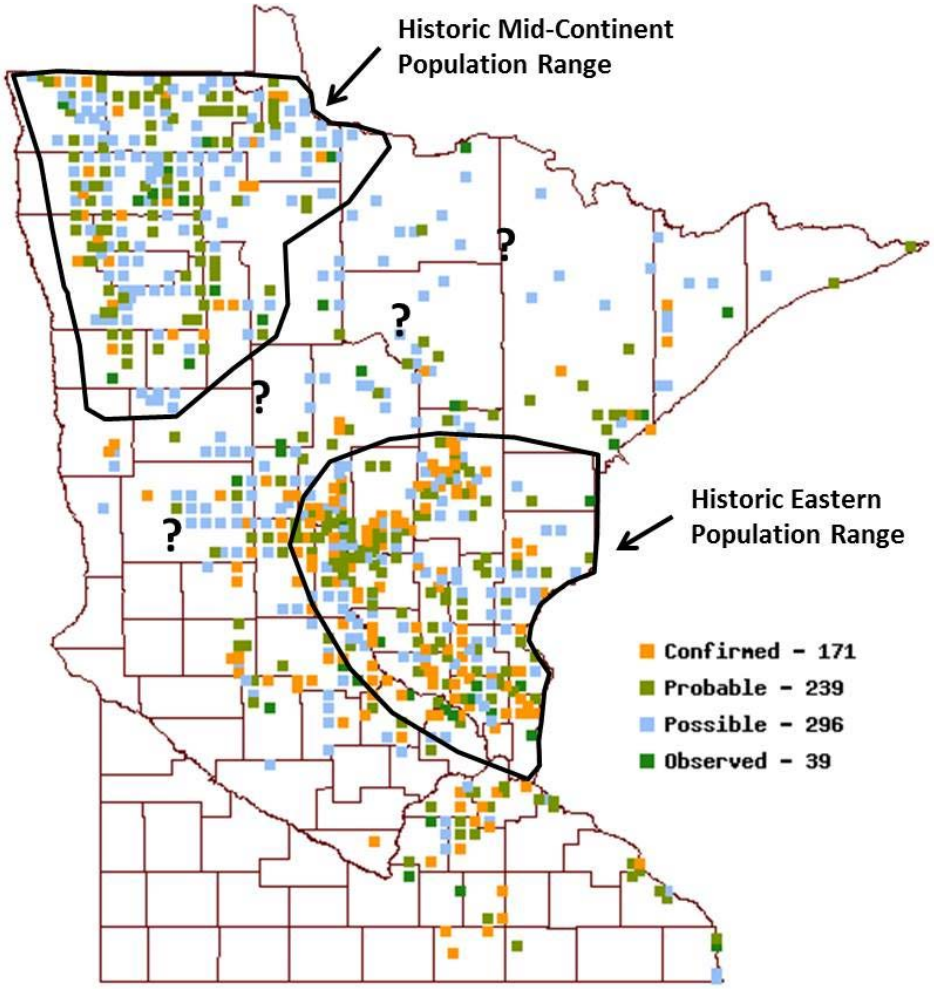


Figure 1. Sandhill crane locations in Minnesota based on preliminary data from the Minnesota Breeding Bird Atlas. The historic breeding ranges of Mid-continent Population and Eastern Population sandhill cranes in Minnesota are delineated by the polygons, while the cranes breeding in the area delineated by question marks are the focus of this proposal. (http://www.mnbba.org/blockmap/cresults.php?species=Sandhill Crane)

Figure 2. Sandhill crane at Crex Meadows, Wisconsin equipped with a tibiotarsus-mounted GPS satellite transmitters and alpha-numeric coded band. GPS – cell transmitters would be attached to sandhill cranes near the presumed boundary between the Mid-Continent Population and Eastern Population cranes in Minnesota as part of the proposed project.

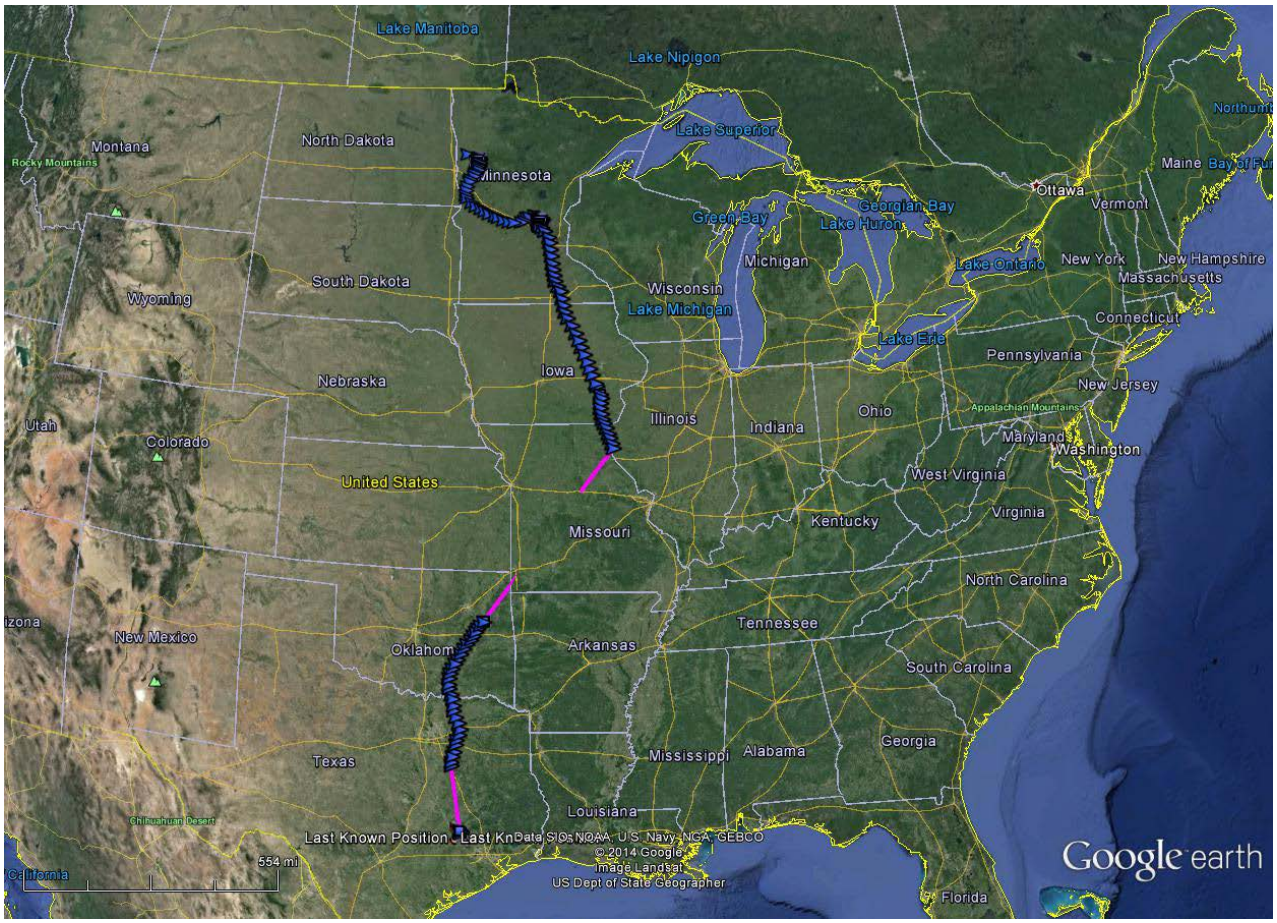


Figure 3. Migration trajectory of a sandhill crane captured in Becker County, Minnesota during fall and early winter 2014.

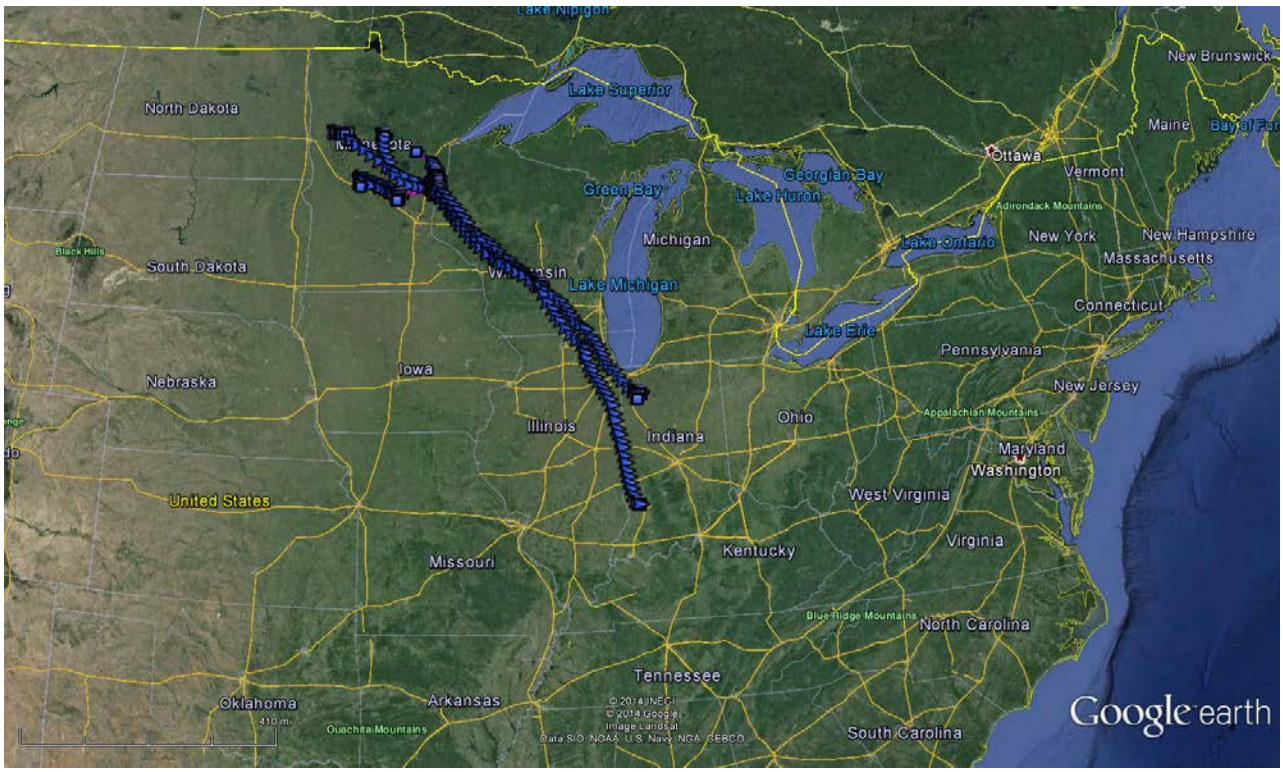


Figure 4. Migration trajectories of sandhill cranes marked in central Minnesota that moved consistent with the migration patterns of Eastern Population cranes in the fall and early winter of 2014.

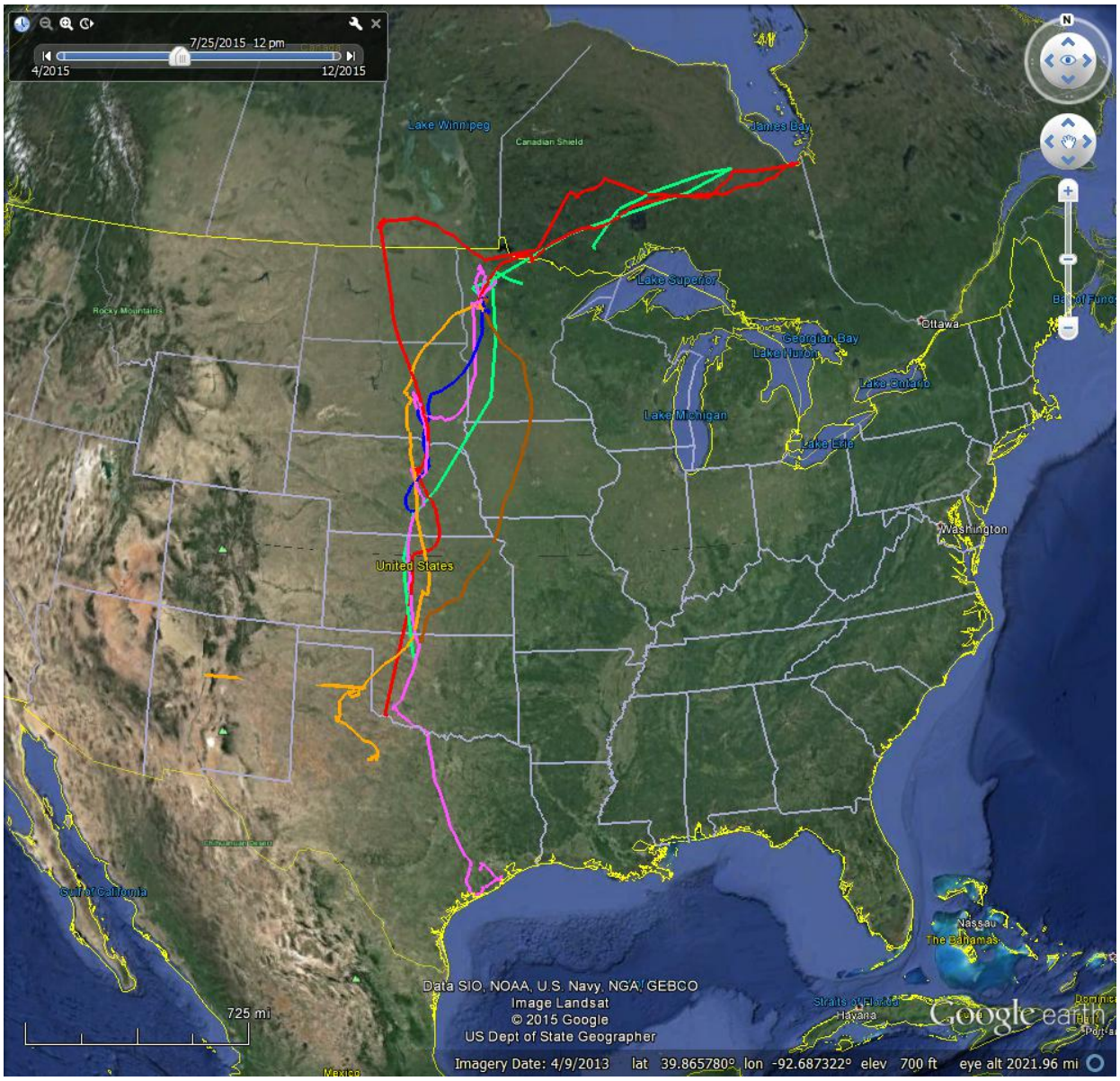


Figure 5. Migration trajectories of Mid-Continent sandhill cranes during the summer and fall of 2015. A total of six trajectories are shown from cranes captured in 2014 and 2015 in the study area.

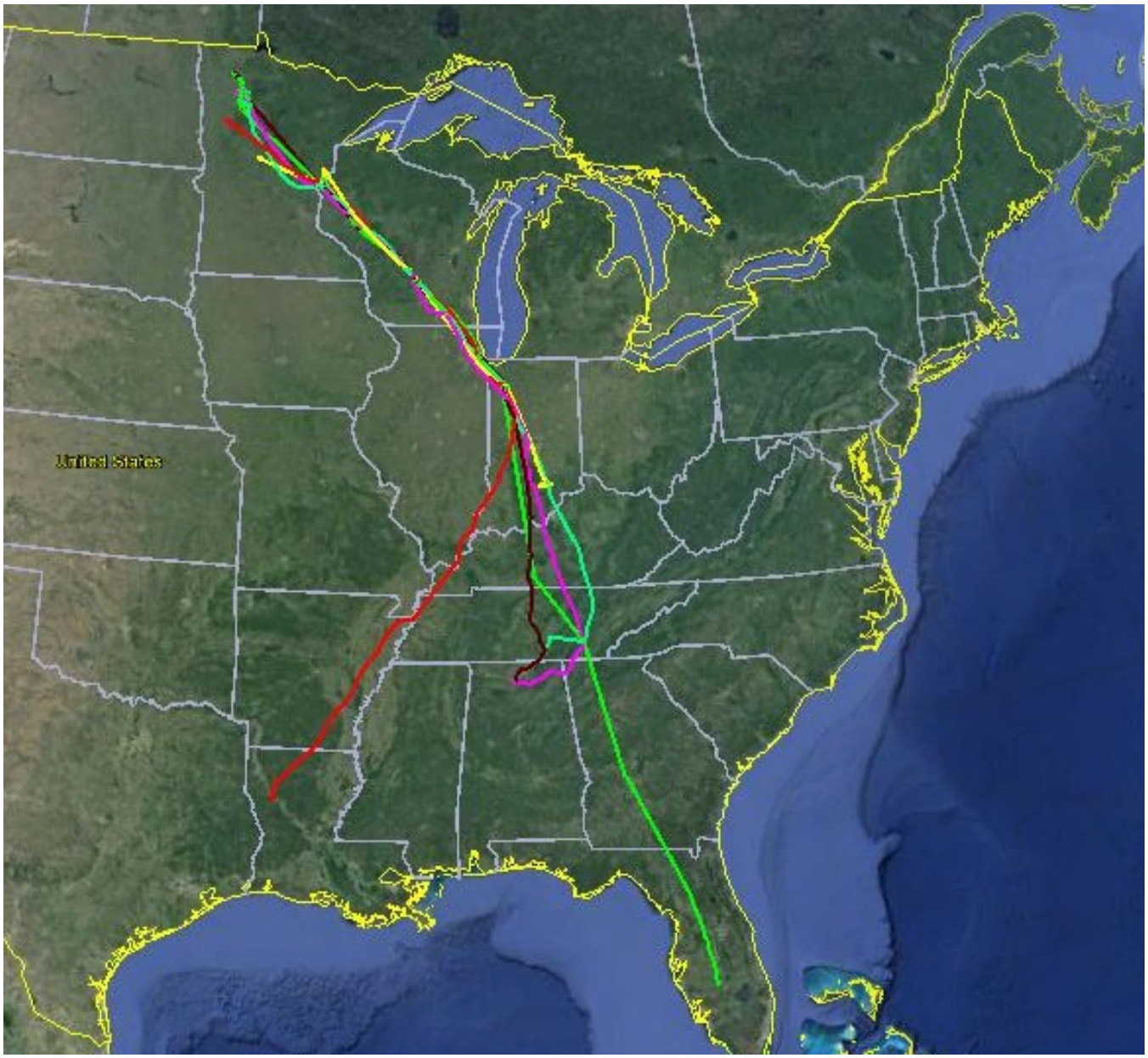


Figure 6. Migration trajectories of 25 Eastern Population sandhill cranes during the summer and fall of 2015.

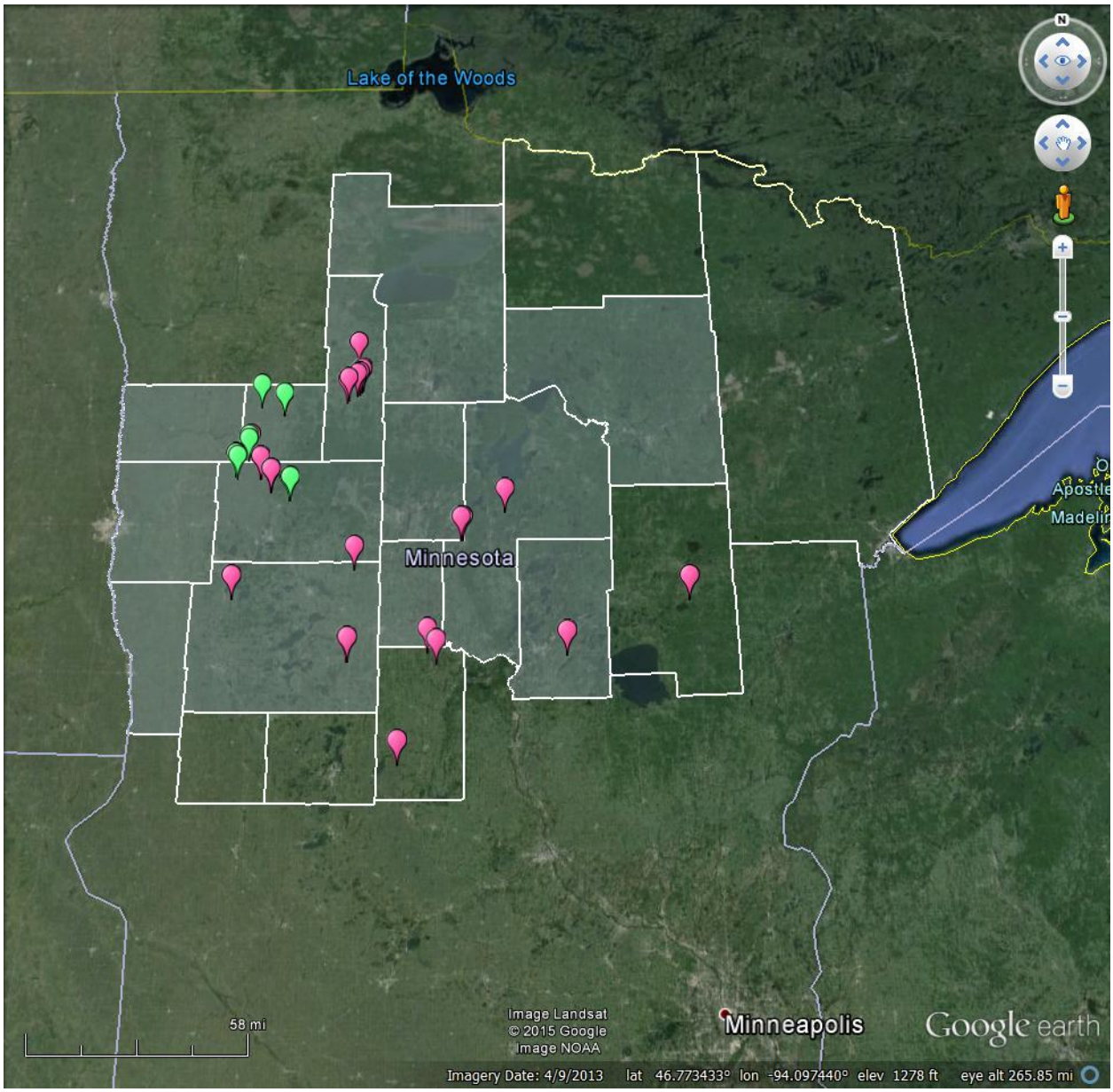
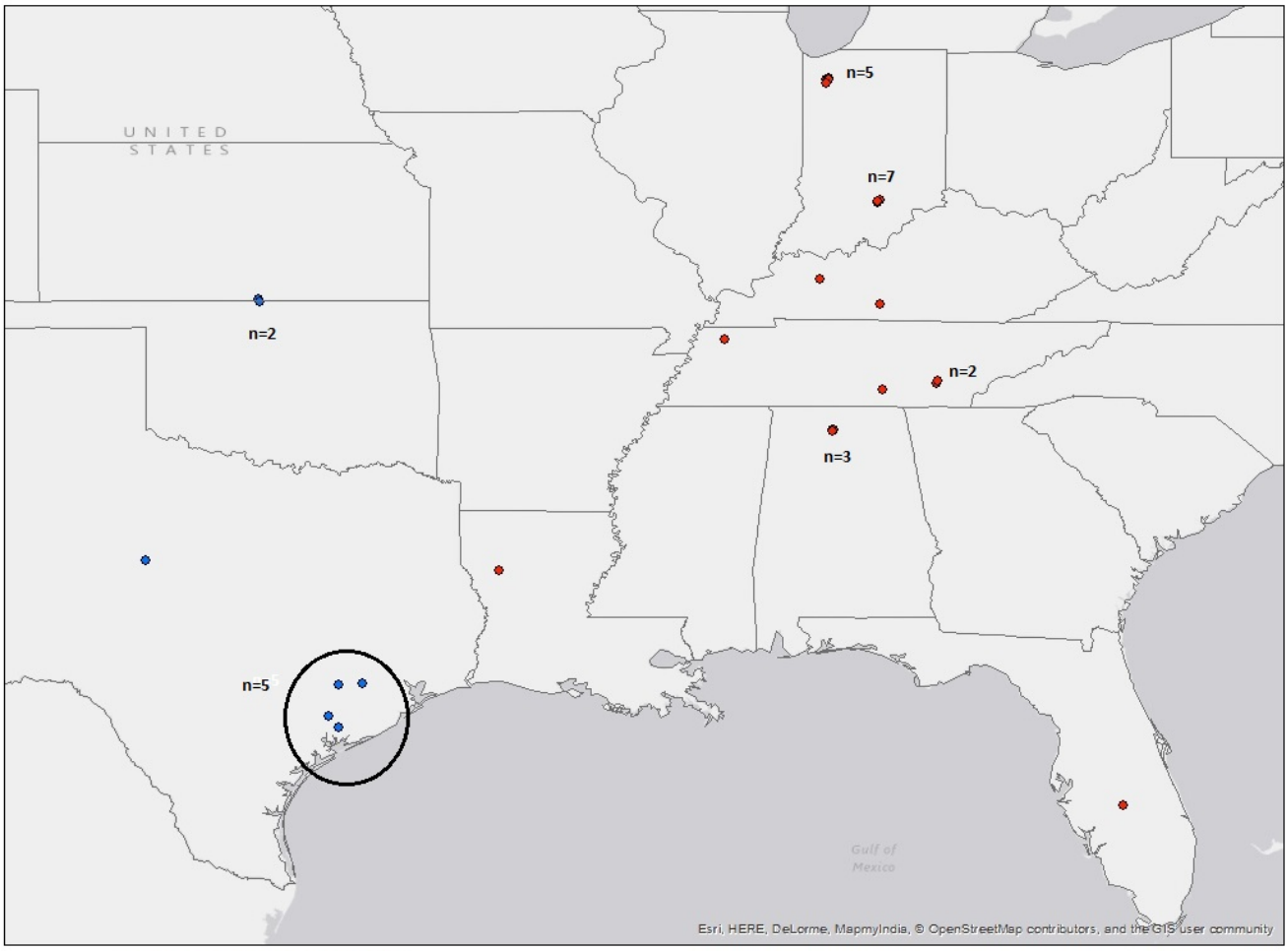


Figure 7. Capture locations of sandhill cranes. Eastern Population cranes are in pink and Mid-Continent cranes are in green (not all cranes are visible because of some clustered capture locations). Counties in the project study area are in white. Shaded counties were prioritized in 2015.



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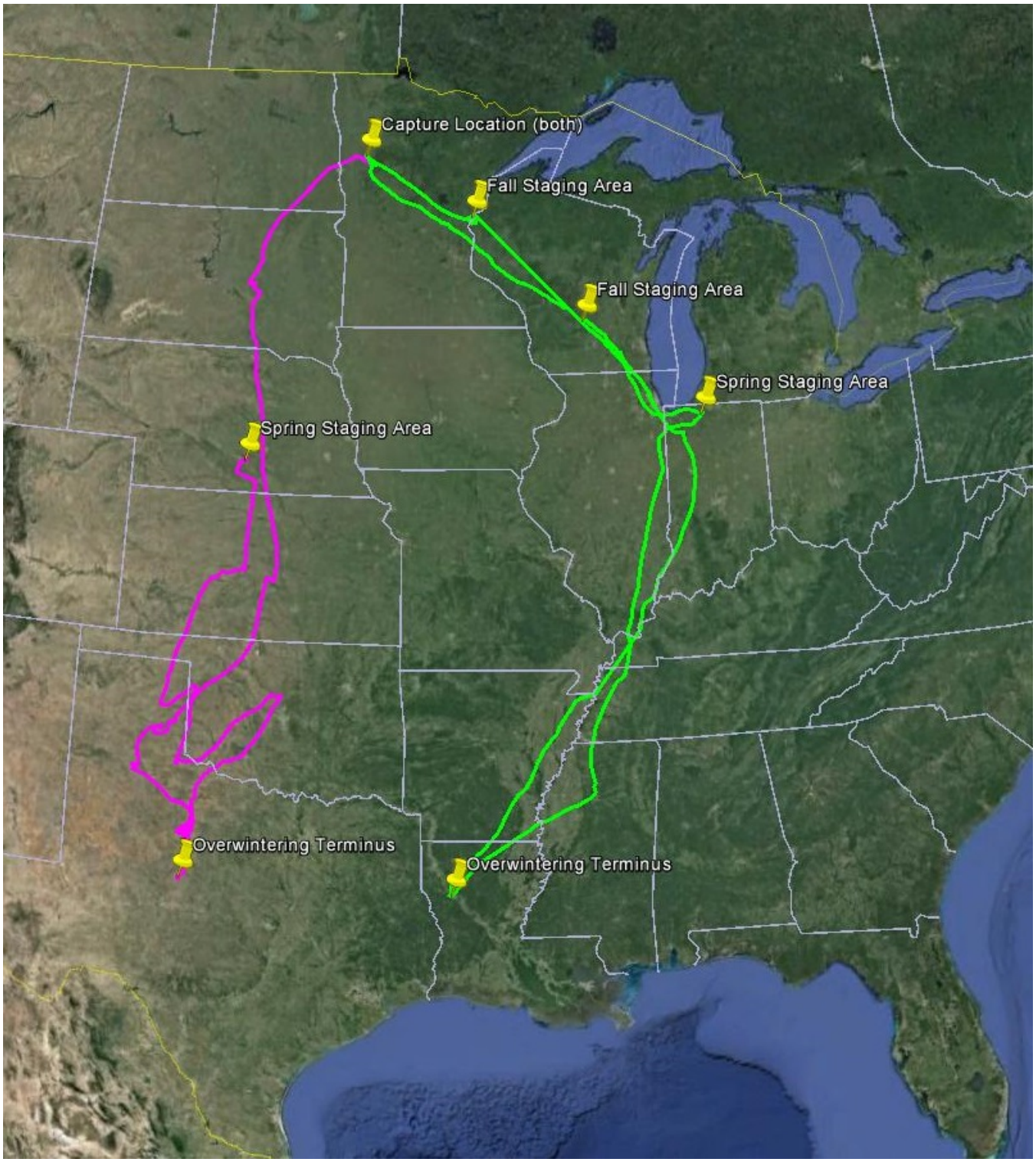

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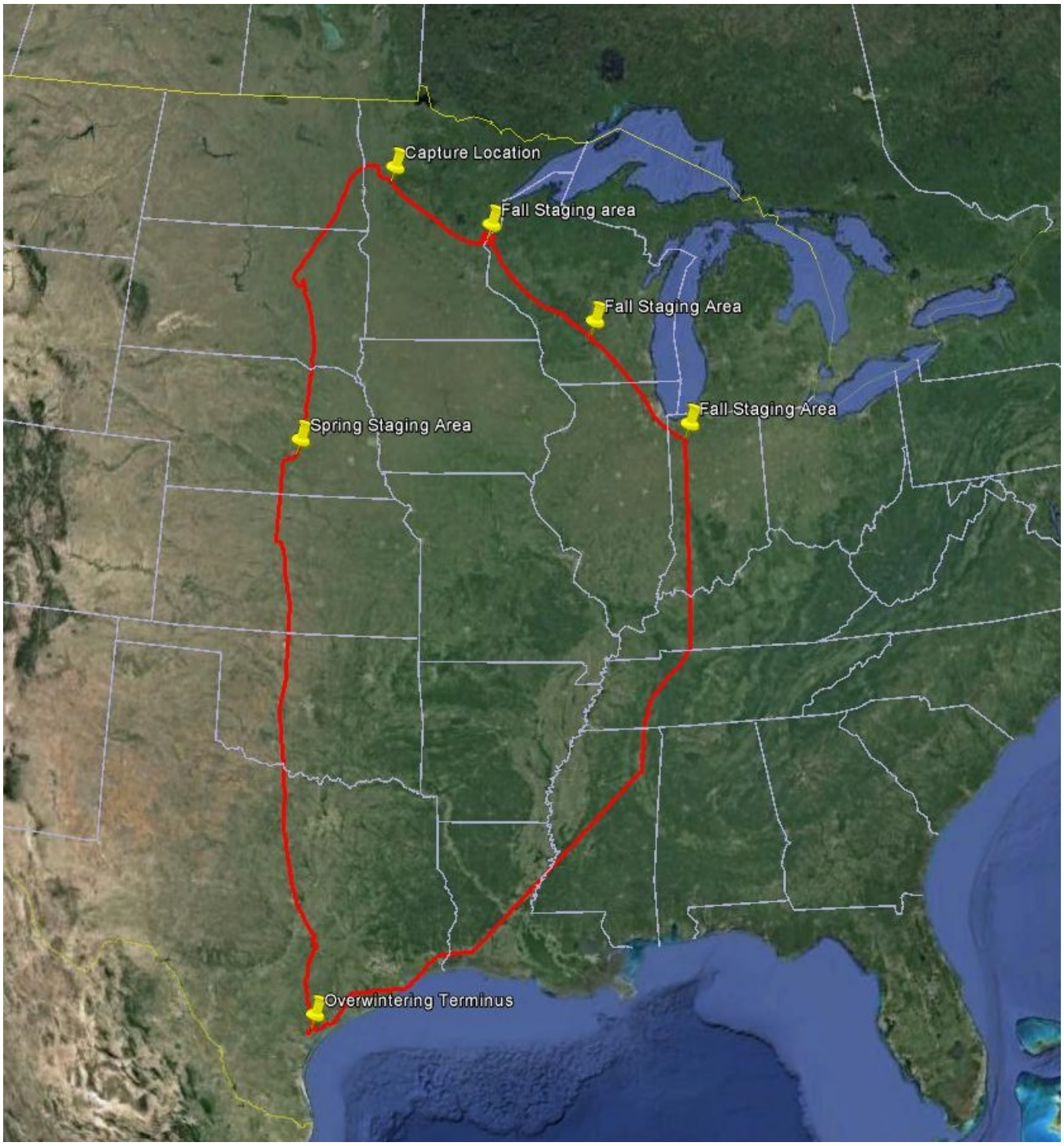

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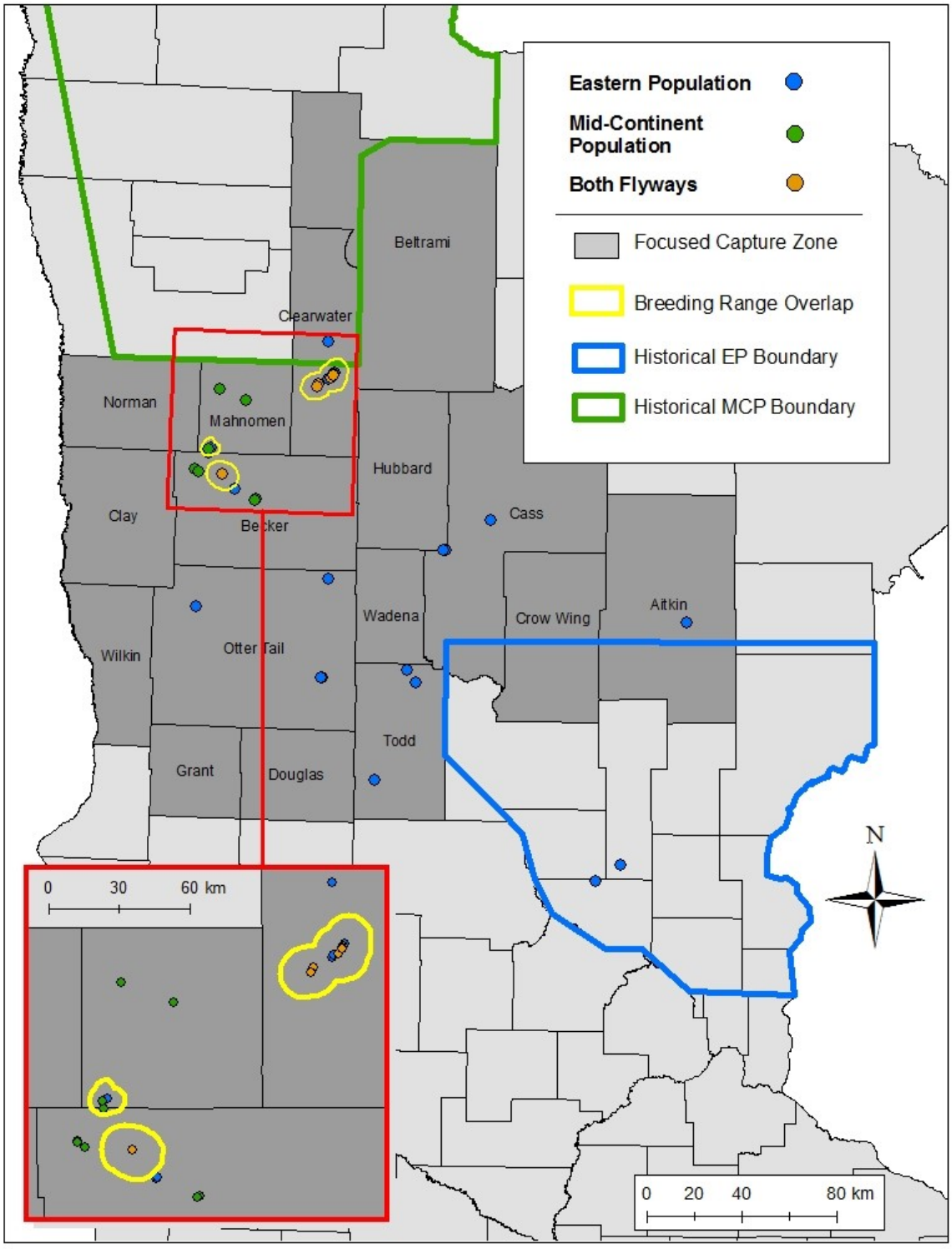

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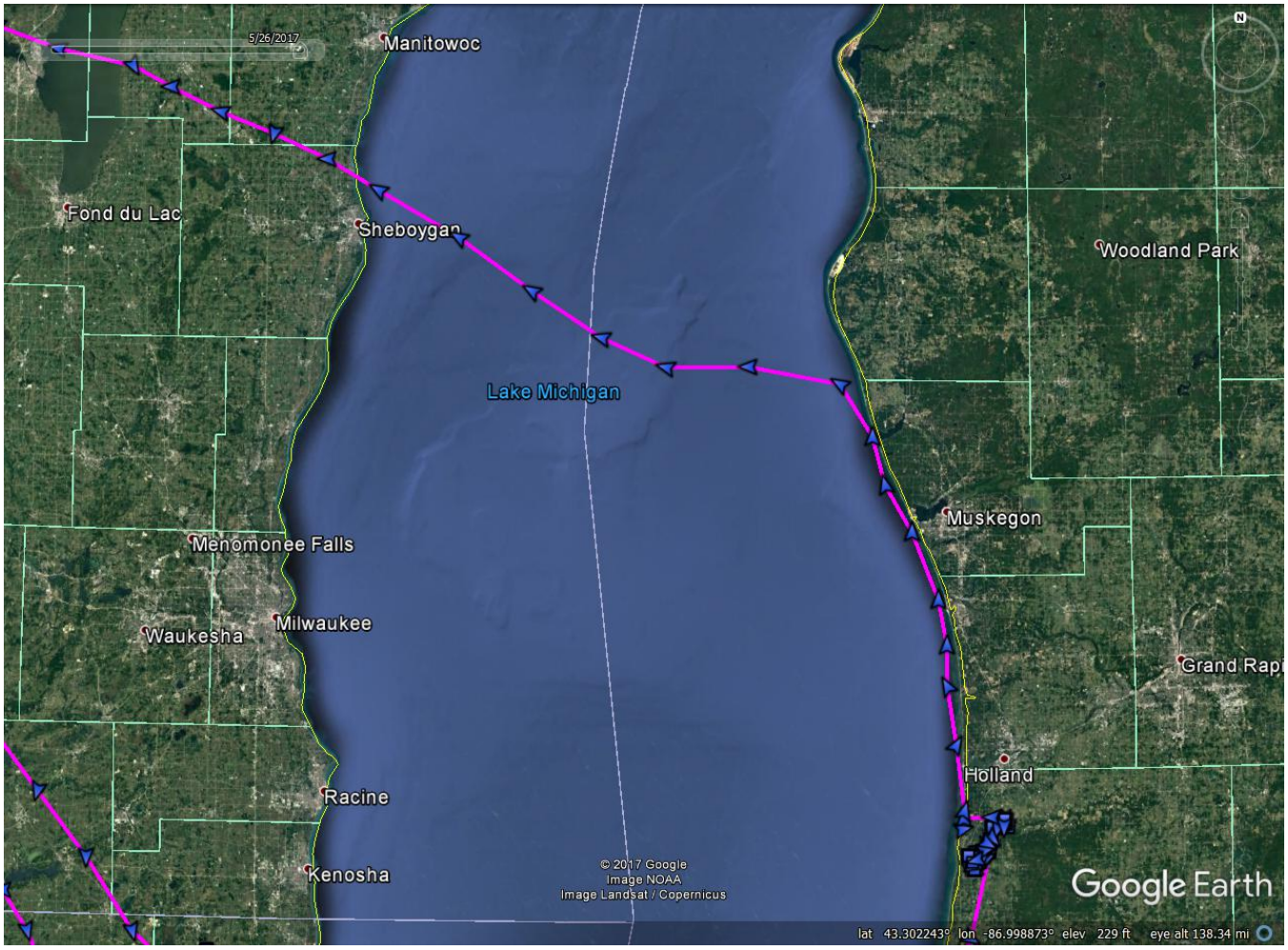

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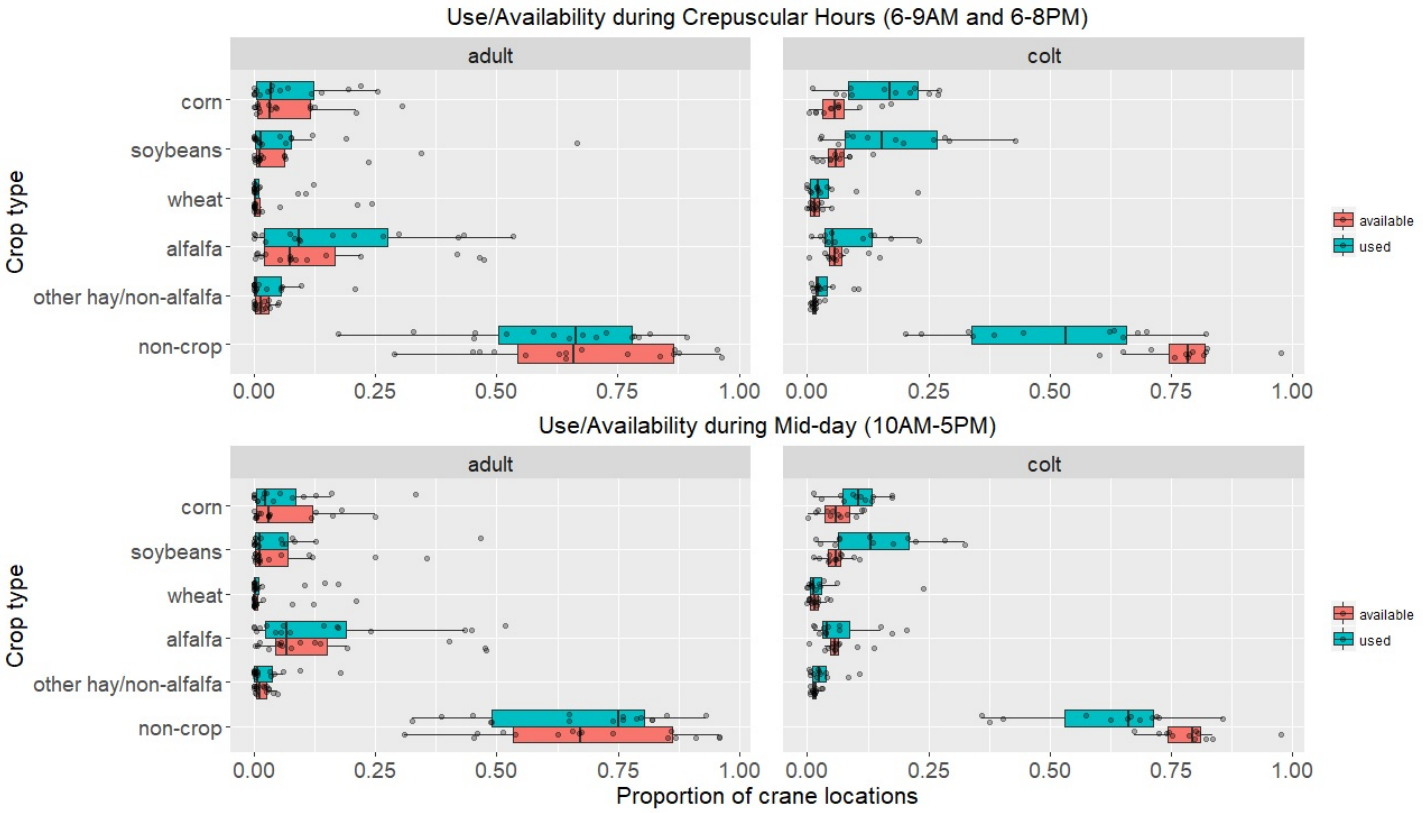

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Table 1. Mayfield survival rate estimates for juvenile and adult sandhill cranes radio-marked in Minnesota from 2014-2015 under differing assumptions regarding the fate of individuals with lost signals. The true survival rates likely fall somewhere between these two sets of estimates.

	Annual survival assuming lost signals were mortality events	95% CI	Annual Survival assuming lost signals were due to transmitter failure	95% CI
Colts	0.44	(0.30,0.63)	0.81	(0.68,0.97)
Adults	0.68	(0.55, 0.85)	1	NA

Environment and Natural Resources Trust Fund

FINAL M.L. 2014 Project Budget

Project Title: *Sandhill Crane Populations and Management in Minnesota*

Legal Citation: *M.L. 2014, Chp. 226, Sec. 2, Subd. 05h*

Project Manager: *David E. Andersen*

Organization: *University of Minnesota, U.S. Geological Survey, MN Cooperative Fish and Wildlife Research Unit*

M.L. 2014 ENRTF Appropriation: $ *250,000*

Project Length and Completion Date: *3 Years, June 30, 2017*

Date of Report: *8 August 2017*

ENVIRONMENT AND NATURAL RESOURCES TRUST FUND BUDGET	Activity 1 Budget	Amount Spent	Activity 1 Balance	Activity 2 Budget	Amount Spent	Activity 2 Balance	TOTAL BUDGET	TOTAL BALANCE
BUDGET ITEM	***Mark 40 sandhill cranes with transmitters***			***Acquire movement and habitat data***				
Personnel (Wages and Benefits)								
*Co-Principal Investigator salary (1 month per year @ $8,944 per month * 2 years, 19.83% fringe benefits rate, 100% appointment for 1 month each year, 83.45% of total in salary and 16.55% in fringe)*				$21,435	$21,435	$0	$21,435	$0
M.S. Student ($37,634 in Year 1 $39,033 in Year 2 approximately 14 months in Activity 1 and 10 months in Activity 2, including tuition [$13,510 in Year 1 and $14,185 in Year 2] and 17.68% fringe, 50% appointment)	$44,139	$43,991	$148	$42,879	$42,558	$321	$87,018	$469
Technician salaries (3 technicians in Year 2 approximately 1 month, $12.55/ hour, 40 hours per week, and 7.9% fringe)	$5,383	$5,531	-$148				$5,383	-$148
Professional/Technical/Service Contracts								
Contracts for data from transmitters suppliers (cell-transmitters and/or PTT GPS - approximately $400 per 12-month period per transmitter * 20 transmitters in Year 1 and 40 transmitters in Year 2 - partially funded by other partner funding - contracted through University of Minnesota process)				$28,025	$28,025	$0	$28,025	$0
Equipment/Tools/Supplies								
GPS-cell or PTT satellite transmitters (40 @ $2,600)	$93,830	$93,830	$0				$93,830	$0
Bands, capture equipment, and miscellaneous field supplies	$257	$257	$0				$257	$0
Travel expenses in Minnesota								
Field crew lodging (4 people at $50/night, 80 nights, plus camping at $16/night), plus facility fees)	$4,500	$4,500	$0				$4,500	$0
Field crew food and supplies (groceries for field crews in lieu of per diem, approximately $120 per week for 4-5 people)	$1,358	$1,358	$0				$1,358	$0
4-wheel drive vehice (2 vehicles@$0.565/mile x 100 miles/day x 80 days/year) - additional vehicle costs provided by partner funding	$8,194	$8,194	$0				$8,194	$0
COLUMN TOTAL	**$157,661**	**$157,661**	**$0**	**$92,339**	**$92,018**	**$321**	**$250,000**	**$321**

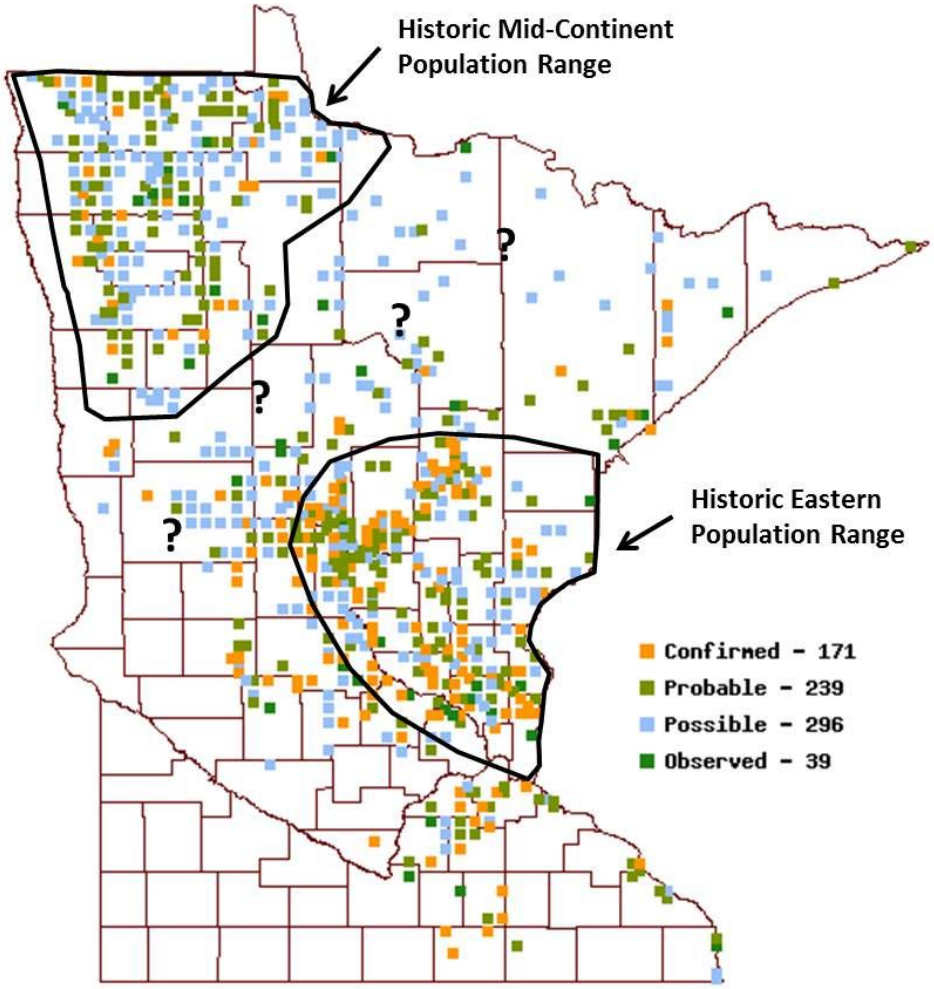


Figure 1. Sandhill crane locations in Minnesota based on preliminary data from the Minnesota Breeding Bird Atlas. The historic breeding ranges of Mid-continent Population and Eastern Population sandhill cranes in Minnesota are delineated by the polygons, while the cranes breeding in the area delineated by question marks are the focus of this proposal. (http://www.mnbba.org/blockmap/cresults.php?species=Sandhill Crane)

Figure 2. Sandhill crane at Crex Meadows, Wisconsin equipped with a tibiotarsus-mounted GPS satellite transmitters and alpha-numeric coded band. GPS – cell transmitters would be attached to sandhill cranes near the presumed boundary between the Mid-Continent Population and Eastern Population cranes in Minnesota as part of the proposed project.

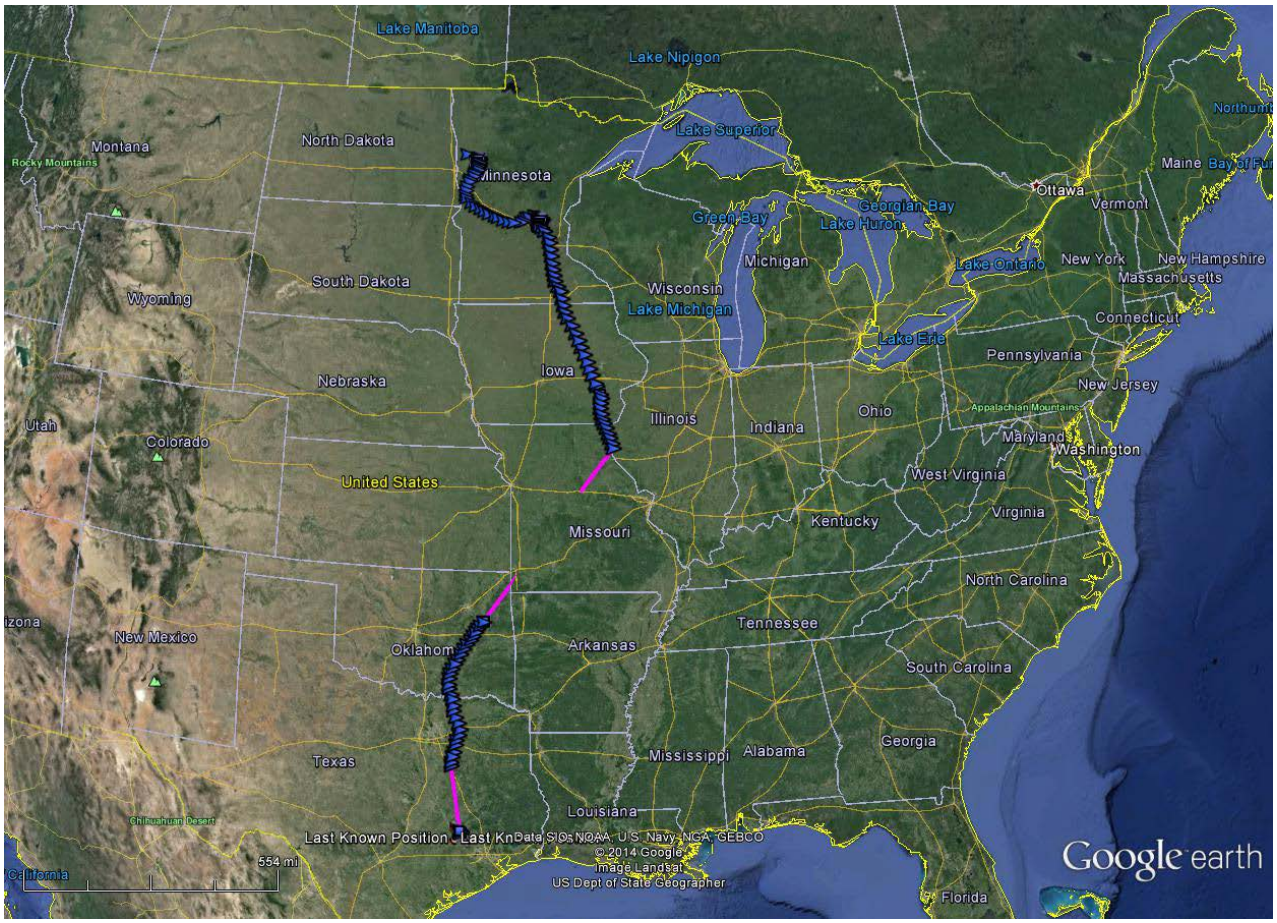


Figure 3. Migration trajectory of a sandhill crane captured in Becker County, Minnesota during fall and early winter 2014.

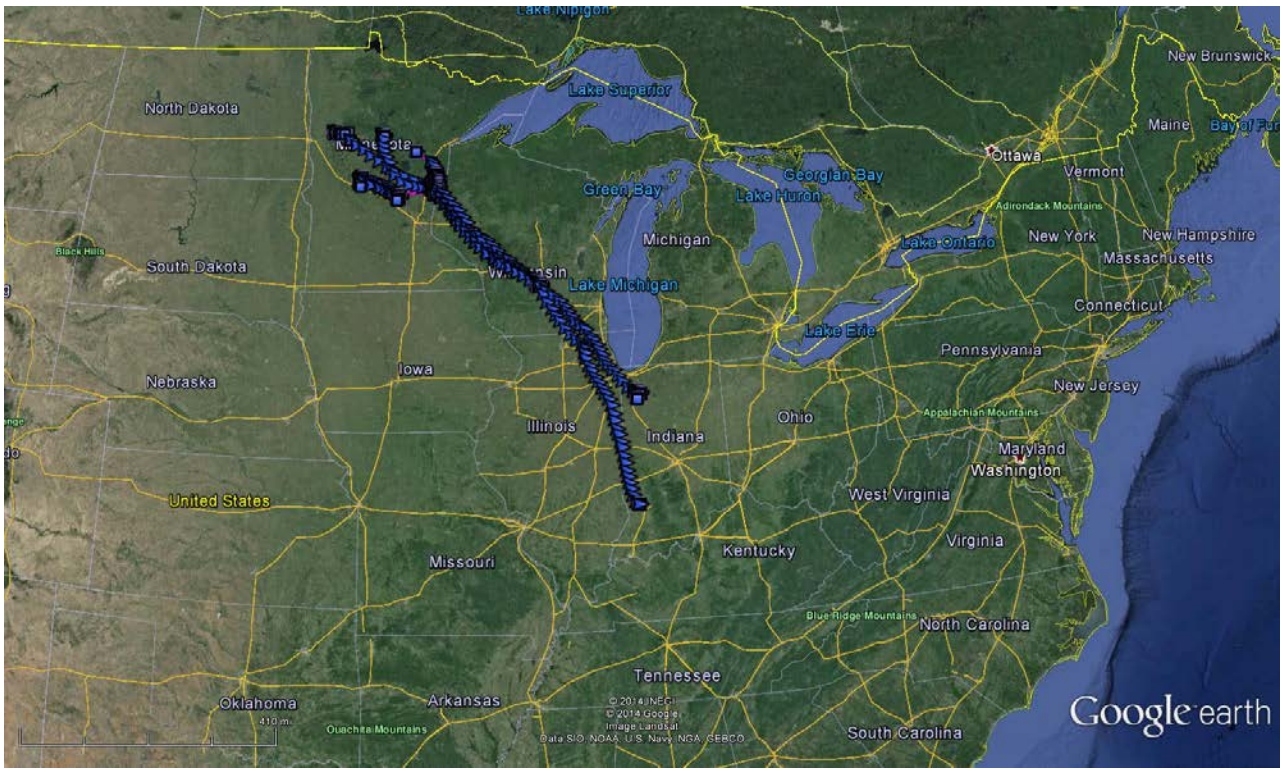


Figure 4. Migration trajectories of sandhill cranes marked in central Minnesota that moved consistent with the migration patterns of Eastern Population cranes in the fall and early winter of 2014.

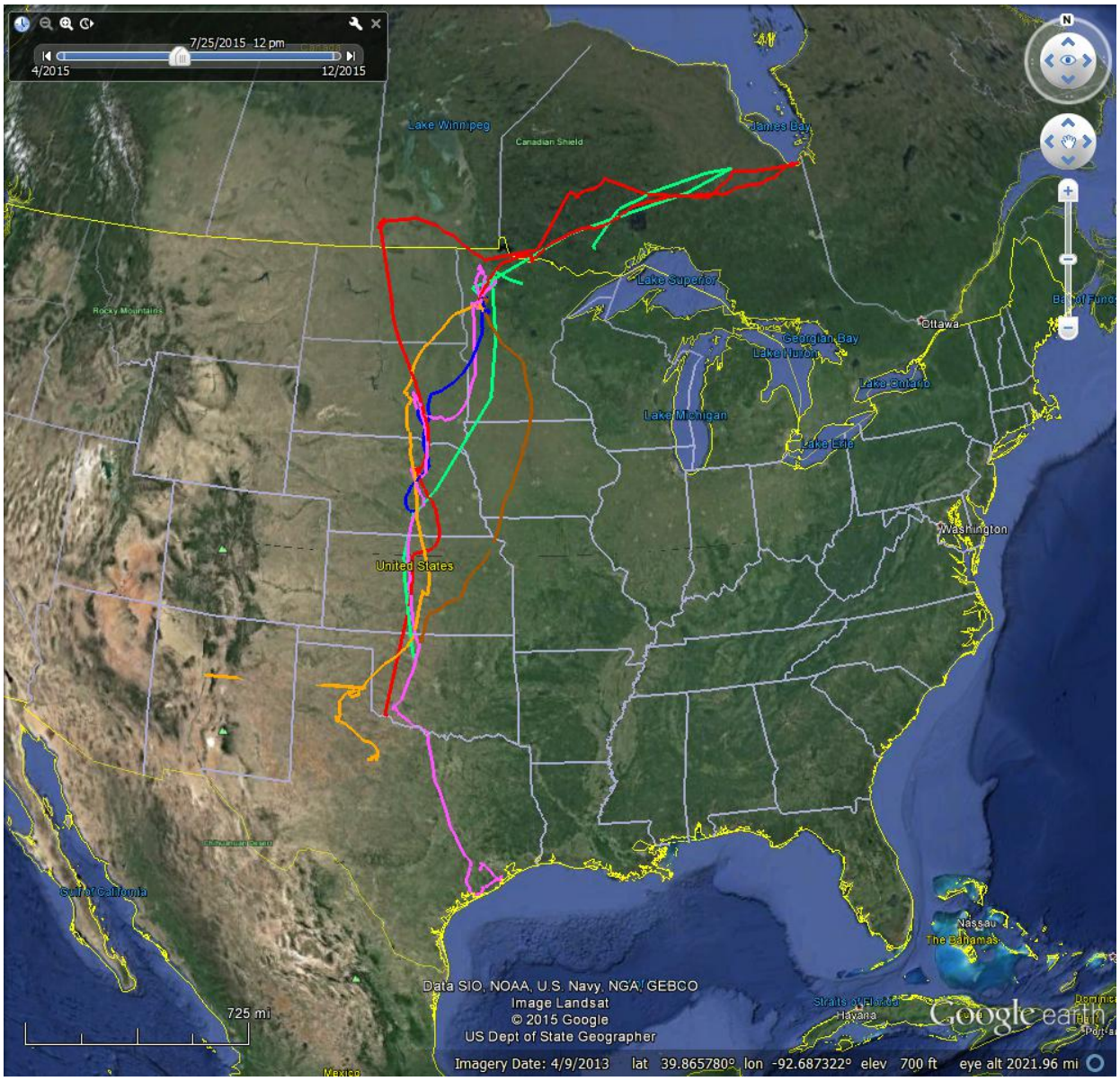


Figure 5. Migration trajectories of Mid-Continent sandhill cranes during the summer and fall of 2015. A total of six trajectories are shown from cranes captured in 2014 and 2015 in the study area.

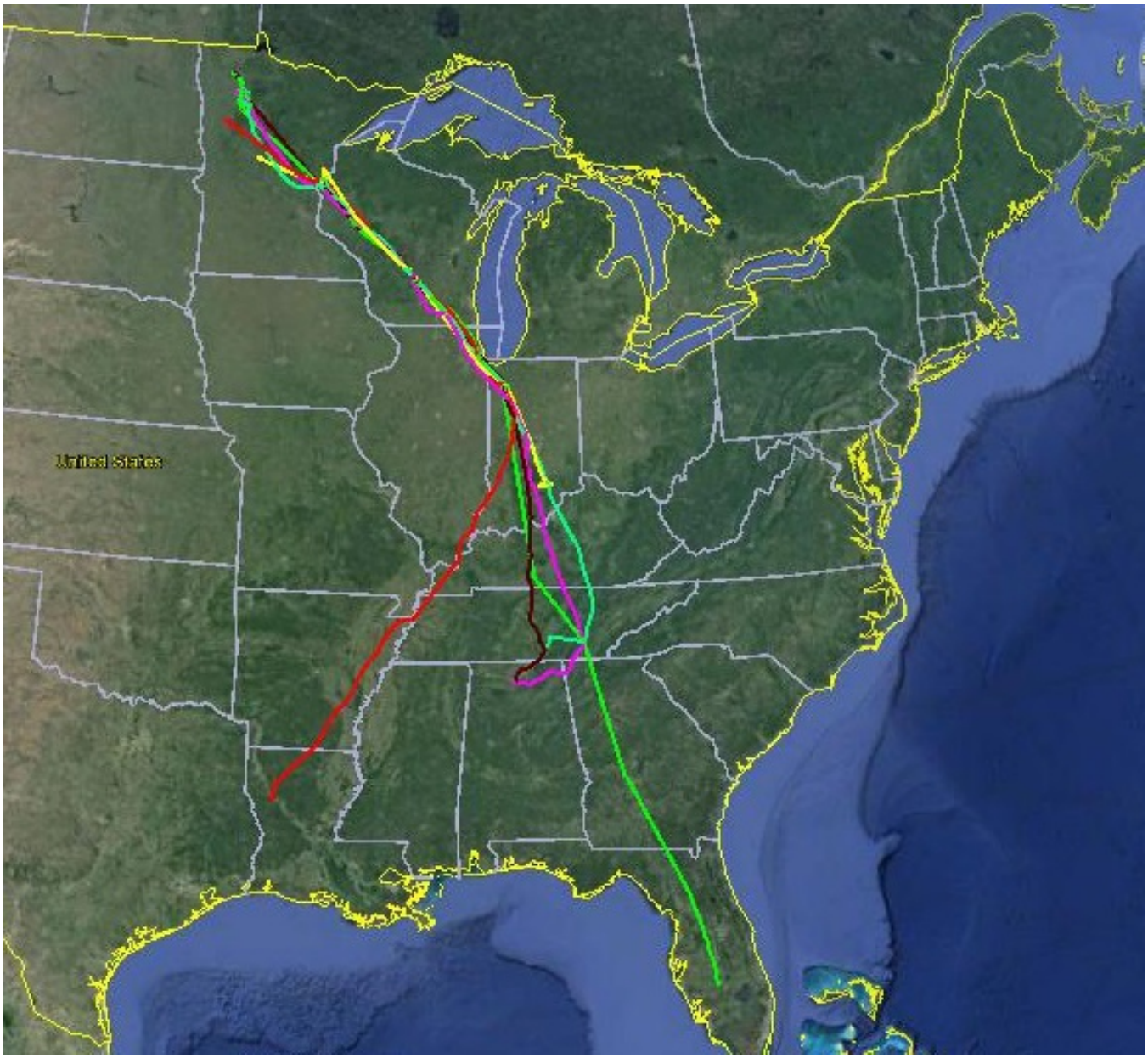
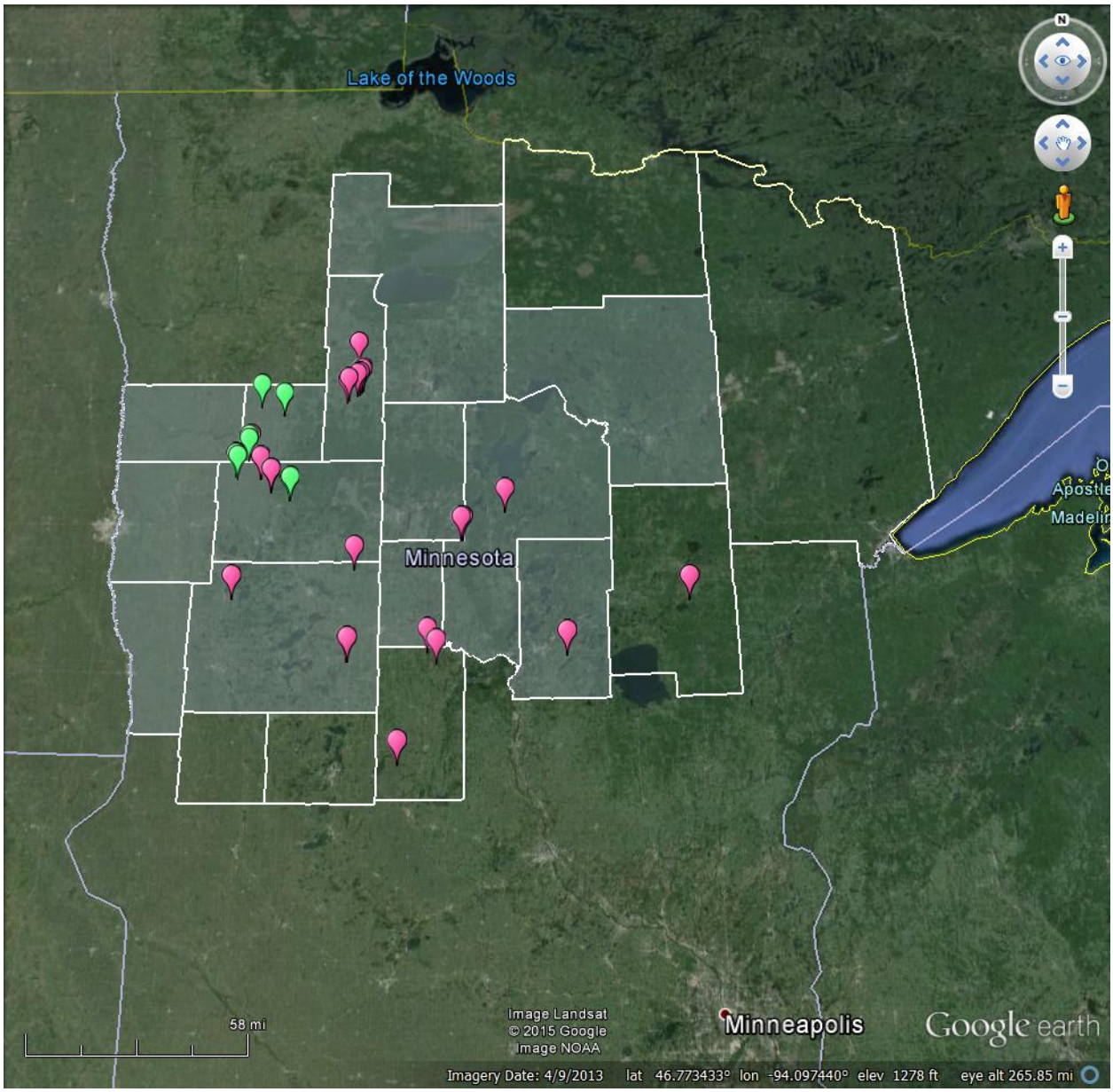


Figure 6. Migration trajectories of 25 Eastern Population sandhill cranes during the summer and fall of 2015.



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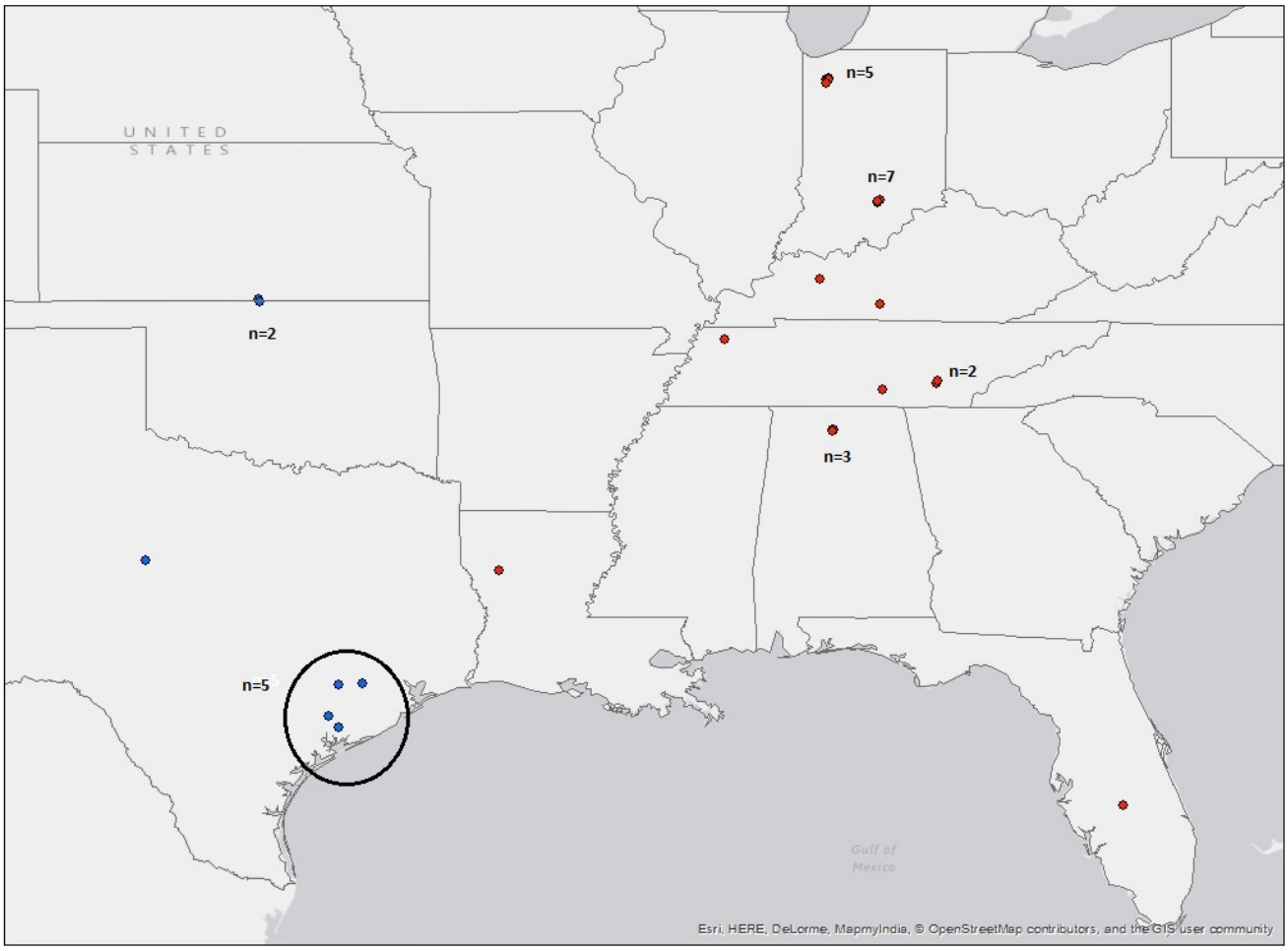

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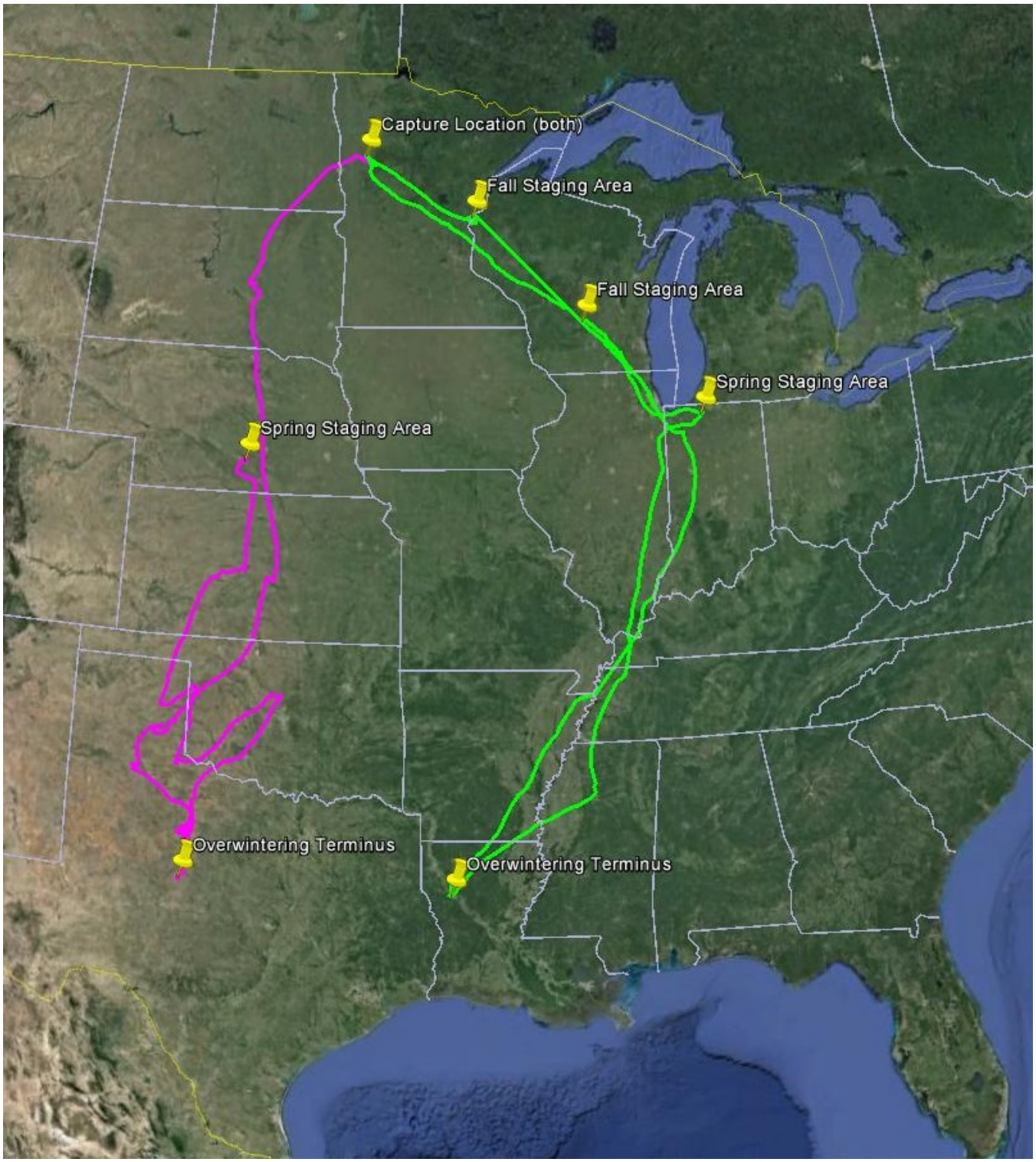

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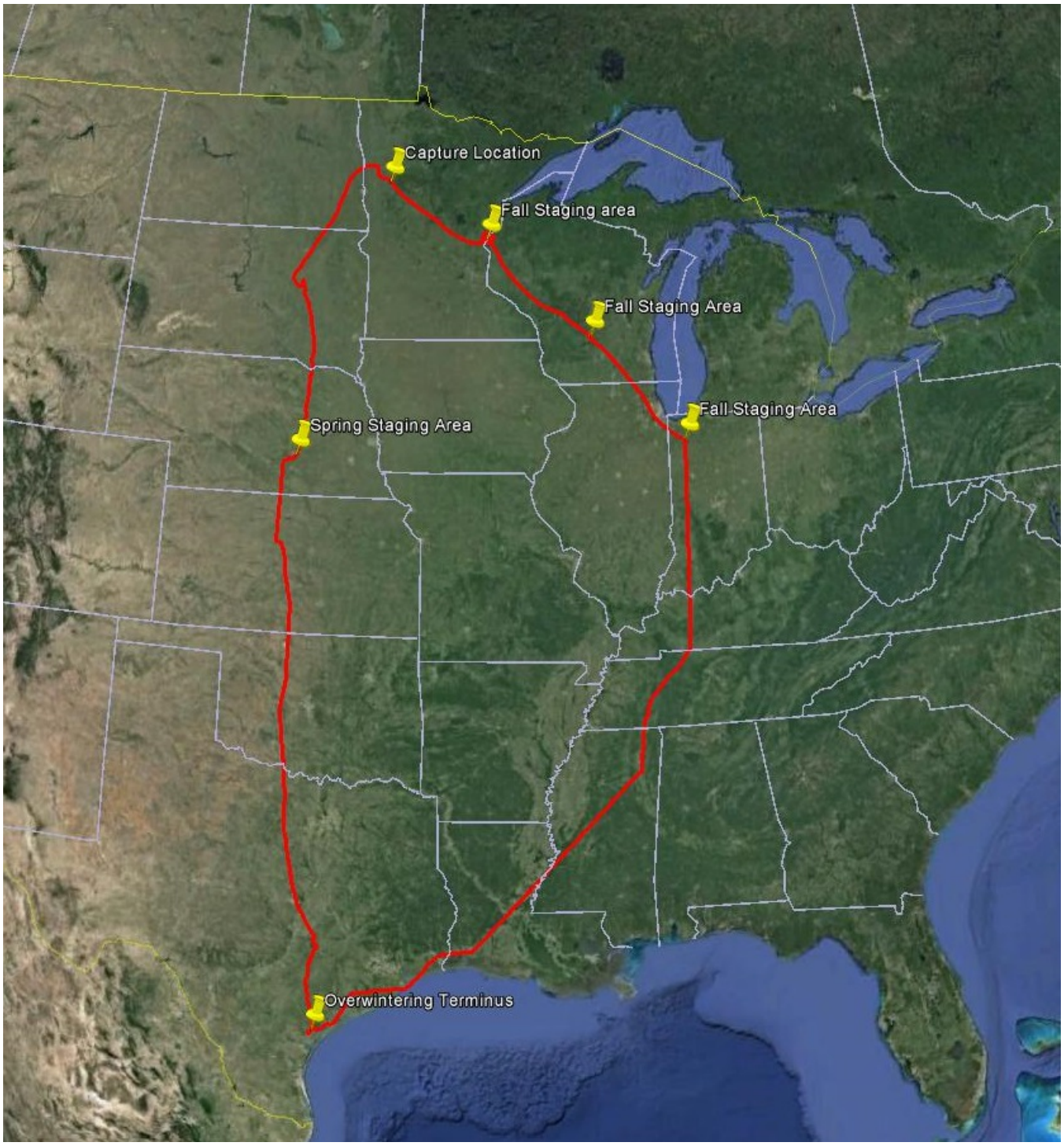

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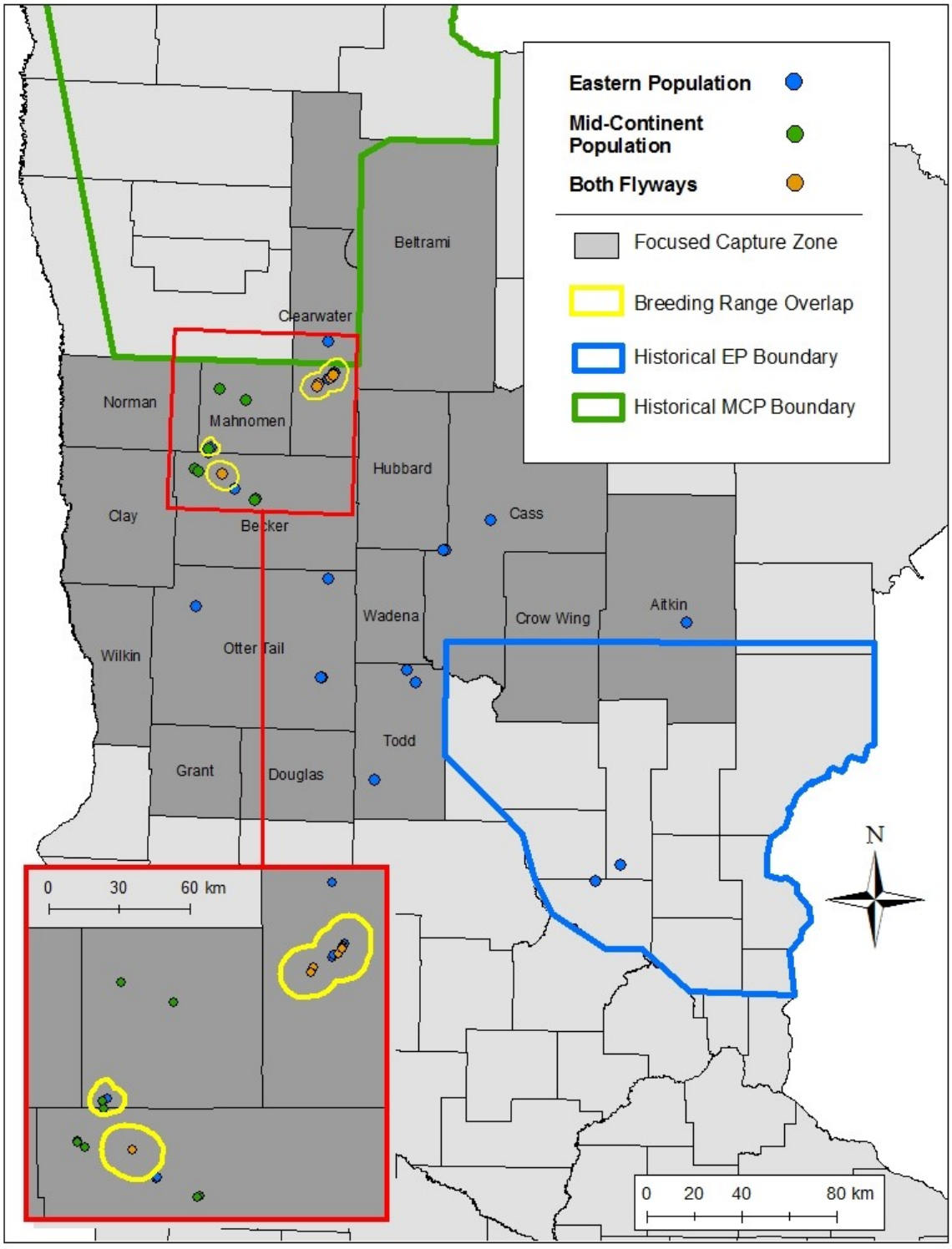

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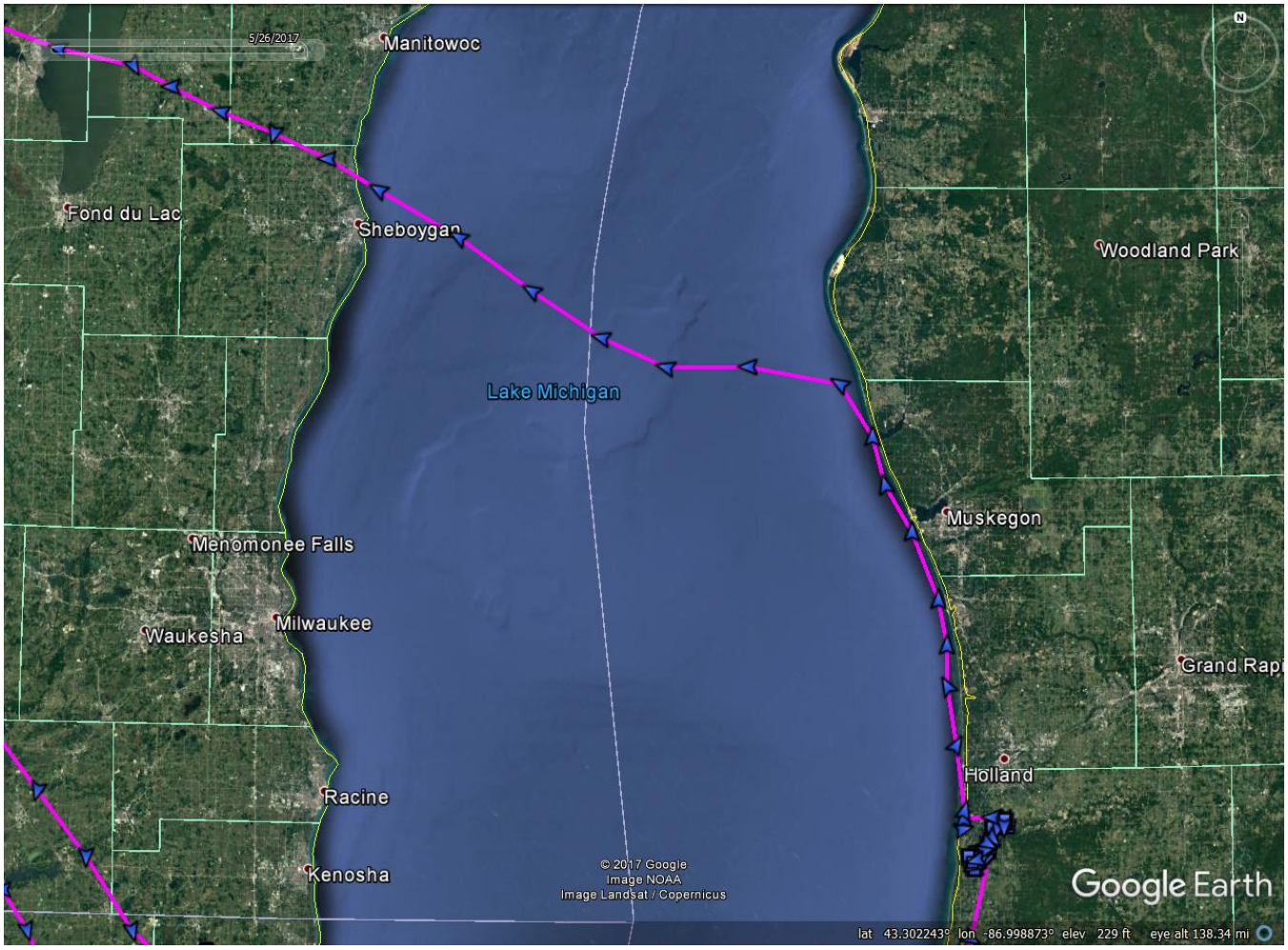

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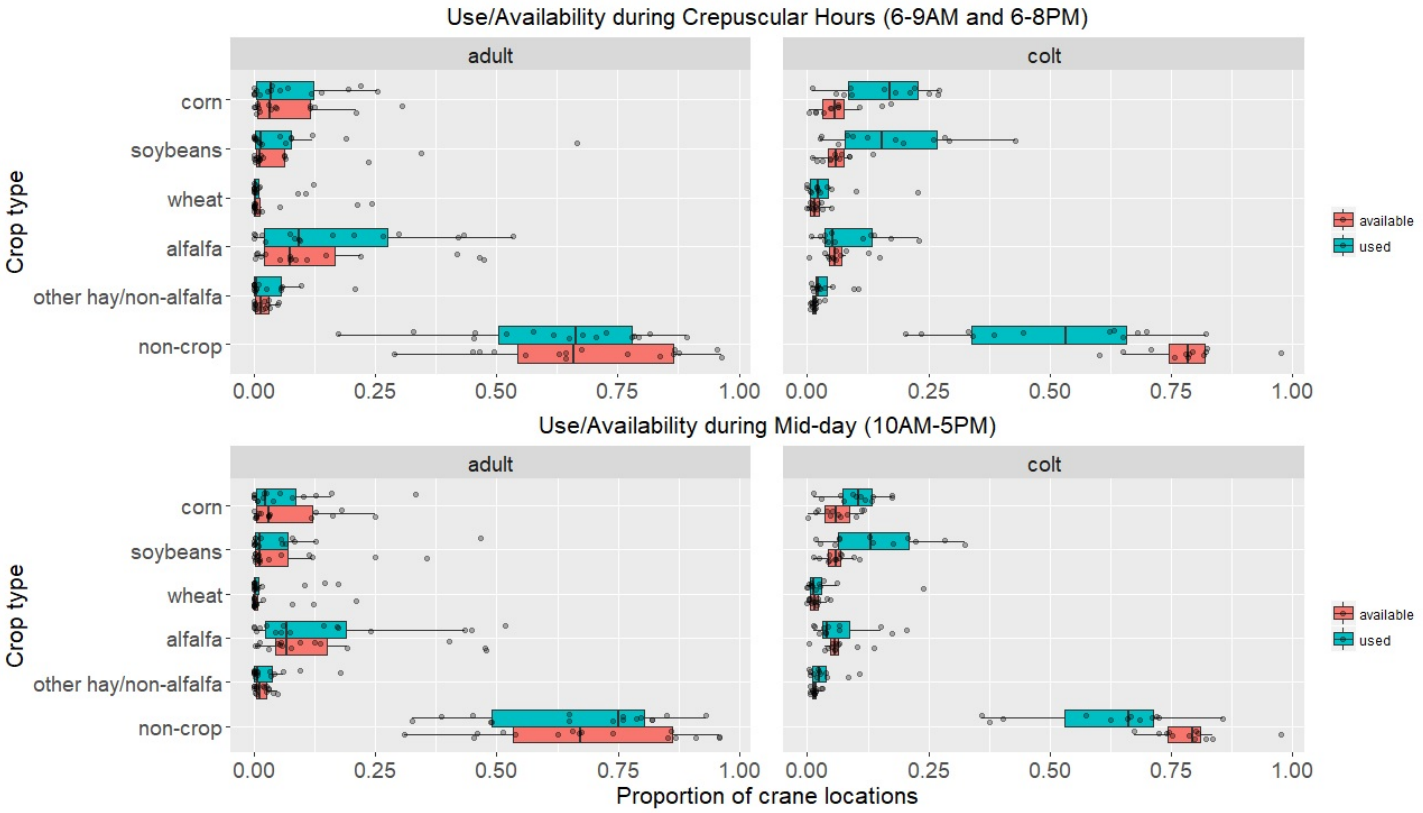

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