CONSERVATION CHALLENGES FOR WHOOPING CRANES (*GRUS AMERICANA*) AND GREATER SANDHILL CRANES (*GRUS CANADENSIS TABIDA*) IN WISCONSIN

By

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A Thesis

Submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

IN

NATURAL RESOURCES (WILDLIFE)

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

December 2014

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ABSTRACT

Abundance estimates allow wildlife managers to make informed management decisions, but differential detectability of individuals can lead to biased estimates of abundance. Sandhill cranes (*Grus canadensis*) are large-bodied and long-lived, rendering them ideal for mark-recapture estimates, but territorial birds have limited movement when compared to non-territorial birds, which may violate the assumption of equal detectability. Our objective was to quantify differential detectability for non-territorial and territorial sandhill cranes on a breeding ground, and to use this information to estimate population size for each group. We hypothesized that territorial sandhill cranes would be detected more often than non-territorial cranes. In 2009, the International Crane Foundation surveyed three routes in Briggsville, Wisconsin, two days per week with six passes per day. Technicians recorded bird locations on an aerial photograph. We created capture histories for banded territorial (n=52) and banded non-territorial cranes (n=23), and used the Huggins closed capture model in program MARK to estimate detection probability and abundance for each group. We identified *a priori* models that may explain daily crane detection over the sampling period using distance from road, territoriality, sampling event (first or subsequent sighting), and time of season as variables. We used Akaike's Information Criterion adjusted for small sample size to rank models. The best approximating model included territoriality and sampling event (AIC_c weight= 0.92). Probability of detection was higher for territorial ($\hat{p} = 0.11$, CI=0.08-0.14) than for non-territorial ($\hat{p}$ =0.03, CI= 0.01-0.07) birds. In subsequent sampling events (each day was considered a sampling event), detection probability almost doubled to 0.18 (CI= 0.17-0.20) for territorial cranes, and almost tripled to 0.11 (CI= 0.09-0.14) for non-territorial cranes. Potential reasons for differential detection include differing degrees of movement by birds and/ or an observer effect in which the ability of observers to spot birds increases over time. We also used the N-mixture model to estimate detection probability and abundance for all cranes in the area (banded and unbanded), and obtained similar results for detection probabilities of banded territorial and banded non-territorial cranes. Abundance estimates for unbanded cranes from the N-mixture model were unrealistically high. Our research demonstrates the importance of differential detection when calculating abundance for sandhill cranes on breeding grounds.

In 1941, less than twenty whooping cranes (*Grus americana*) remained in one wild population wintering at Aransas National Wildlife Refuge, Aransas, Texas (Allen 1952). This population had increased to 257 (95% CI 178-362) in the winter of 2012 (Harrell and Bidwell 2013).The United States Fish and Wildlife Service began reintroducing whooping cranes into Wisconsin in 2001, but this population is not self-sustaining (WCEP 2012) potentially because nest success is low. Several hypotheses have been proposed for low nest success including improper nesting behavior resulting from captive rearing techniques. In addition to typical nesting behaviors, Wisconsin whooping cranes may lack adaptive behaviors for coping with ectoparasites specific to the breeding grounds in Wisconsin. Greater sandhill cranes *(G. c. tabida)* also breed in Wisconsin, and seem to exhibit adequate nest success. We aimed to identify behaviors that differ between nesting whooping cranes and sandhill cranes to better understand why population growth is limited in the reintroduced population of whooping cranes breeding at Necedah National Wildlife Refuge. From March – June 2014, we observed nesting behavior through trail cameras programmed to take one photo every five minutes. During

nesting, we monitored nests until either eggs hatched or nests were abandoned. Nine whooping crane nests and seven sandhill crane nests were used for analysis. We identified behaviors (incubating, away from nest, manipulating nest platform, etc.) in 16,487 sandhill crane and 25,544 whooping crane photographs. Apparent nest success was 0.56 for whooping cranes and 0.57 for sandhill cranes during the 2014 breeding season. All whooping crane nest failures were abandonments while sandhill crane nests failed for various reasons including predation. We used a two way factorial ANOVA with sub-sampling and found that birds on nests where one egg hatched spent significantly more time incubating eggs for both crane species ($F_{(0.5),1,12}$ =14.24, P = 0.0027). Additionally, whooping cranes spent more time away from nests than sandhill cranes ($F_{(0.5),1,12}$ =5.3, P = 0.0395) and cranes of both species that had successful nests spent less time away from the nest ($F_{(0.5),1,12}$ =11.7, P = 0.0051). Cranes with successful nests spent less time manipulating eggs than those with unsuccessful nests ($F_{(0.5),1,12}$ = 16.97, P = 0.0014). All other behaviors were not significantly different between cranes with successful and those with unsuccessful nests or between whooping cranes and sandhill cranes. At this time, we do not know if birds abandoned nests because the eggs were not fertile or if eggs did not hatch because adults left the nests. Behavior differences are confounded with species, rearing (captive or wild), and genetic differences. We also caution the interpretation of the data because we only monitored 16 total nests over one nesting season. However, this first year of data collection supports our hypothesis that whooping cranes and sandhill cranes exhibit some behavioral differences.

ACKNOWLEDGEMENTS

This research was facilitated by funding from the U.S. Fish and Wildlife Service, and support from The International Crane Foundation and the University of Wisconsin – Stevens Point. I would like to thank my advisor, Shelli Dubay, for all the support, encouragement, and knowledge that she provided over the past two years. I thank my other committee members, Jason Riddle, Brad Strobel, and Tim Ginnett, for their time and expertise.

I would like to thank the International Crane Foundation for assistance and guidance and especially for providing flights to locate sandhill crane nests during my second field season. Jeb Barzen was an influential advisor, and I am thankful for his time and input which have improved the quality of this thesis. Additionally, Anne Lacey, Andrew Gossens, and Julie Langenberg provided essential aid and advice. Regan Dohm, Julia Welch, and Hen Bellman provided essential data collection and friendship.

I would like to thank Brad Strobel for allowing me to be part of the whooping crane research completed at NNWR. His expertise and direction were invaluable to the completion of this thesis. Doug Staller and Richard King were also instrumental in my initial introduction to the refuge and their advice was greatly appreciated. Jessica Jaworski, Trevor Lauber, Scott Collins, and Gaelyn Ong provided expert assistance in data collection. Michelle Willis was crucial to the completion of behavioral data analysis, and an amazing office mate.

Finally, I would also like to thank my family and friends for all the love and support they gave me through this process. The graduate student community at UW Stevens Point has made my experience here immensely better with their encouragement

and friendship. I dedicate this thesis to my grandmother, Lois Hungerford, who always encouraged me to continue learning.

TABLE OF CONTENTS

Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PREFACE

The two chapters of this thesis were written using the format of the Journal of Field Ornithology. Data for chapter 1 was graciously provided by The International Crane Foundation. The chapter could not have been written without the expert help of Jeb Barzen, Andrew Gossens, and Anne Lacey. Data for chapter two was obtained with the help of Necedah National Wildlife Refuge. Dr. Brad Strobel and many interns were instrumental in the completion of the chapter.

CHAPTER 1:

PROBABILITY OF DETECTION AND POPULATION ESTIMATION FOR GREATER SANDHILL CRANES

INTRODUCTION

Cranes are large and long-lived wading birds with distinctive, boisterous calls (Archibald and Lewis 1996). Worldwide, nine of the fifteen species of crane are threatened or endangered (Archibald and Lewis 1996), and several life history traits, such as delayed breeding and small clutch size, predispose cranes to low recruitment rates (Walkinshaw 1973). Sandhill cranes (*Grus canadensis),* are one of two crane species found in North America (Archibald and Lewis 1996). The greater sandhill crane (*G. c. tabida*) is the largest North American subspecies of sandhill crane with an average male wing length of 0.54m and an average weight of 5.38 kg (Johnsgard 1983; Archibald and Lewis 1996).

Populations of sandhill cranes declined significantly across North America in the early twentieth century due to hunting and loss of habitat (Henika 1936, Johnsgard 1983). However, sandhill cranes are no longer threatened. In 2013, the USFWS fall count of the Eastern Population (EP) of sandhill cranes, was 87,796 (Kruse et al. 2013). Five populations of greater sandhill cranes are managed separately in the United States (Central Valley, Lower Colorado River Valley, Eastern, Rocky Mountain, and Mid-Continent). In 2010, a management plan permitting hunting was adopted for the EP by the Mississippi and Atlantic flyway councils (Van Horn et al. 2010; USFWS 2011). Kentucky became the first state to issue hunting licenses for sandhill cranes in the EP in 2011 (Kruse et al. 2012). Population estimates for this once threatened species are required in order to set hunting quotas at levels which will both maximize recreational use and protect this population in perpetuity. We sampled a population of greater sandhill cranes in Briggsville, Wisconsin to test a potential population estimation method for EP cranes. Birds have been captured and banded in this population for over 20 years by the The International Crane Foundation (ICF) (Hayes and Barzen 2006).

Crane populations often are estimated using an index of abundance, such as point counts (Walkinshaw 1953; Benning et al. 1987; Pogson 1991; Drewien 1996; Johnson et al. 2001; Kinzel et al. 2006; Stehn and Taylor 2008; Aguilera 2010; Kruse 2012). For example, the USFWS coordinated fall survey has been used to monitor the EP since 1979 (Van Horn et al. 2010). The survey is conducted by employees and volunteers who count cranes at known migratory staging areas around October 31st each year (USFWS 2011, Kruse et al. 2013). Similarly, managers of the Mid-Continent Population (MCP) of sandhill cranes use an index composed of counts from aerial transects to monitor the MCP of sandhill cranes (Benning and Johnson 1987).

Over time, problems associated with survey methods have been identified and efforts were subsequently made to improve the precision of crane counts. For example, the number and location of surveyed areas by the USFWS fall survey has varied through time which creates problems when trying to draw conclusions from the survey results (Amundson and Johnson 2010). Recent assessments have suggested a standardized protocol (Amundson and Johnson 2010). In an effort to improve the precision of the MCP index, nocturnal aerial surveys and infrared cameras were used to pinpoint the time at which the greatest number of sandhill cranes were at roost, and thus available for counting (Kinzel et al. 2006). In addition, aerial photographs of a subset of transects are used to correct for observer error in estimating the number of cranes in large groups (Benning and Johnson 1987).

Standardized protocols and aerial photographs have increased precision of indices to crane abundance. However, indices still may not accurately estimate crane populations for several reasons. First, an index derived from random transect sampling can be misleading if the species is not uniformly distributed, as differences in habitat and aggregations may influence the sampling area required to accurately reflect population size (Johnson et al. 2001). Second, an index does not incorporate detection probability. Instead, detection is assumed to be constant temporally, spatially, and between individuals (Nichols et al. 2000; MacKenzie et al. 2002; Rosenstock et al. 2002; Thompson 2002). This assumption is most likely not met in many surveys. Conway and Gibbs (2011) calculated the effects of several different variables on marsh bird detection probability, and found that types of playback calls used, time of season, time of day, and density affected detection probability of marsh birds. Other researchers have found group size, animal activity, topography, survey type, and tidal height to affect detection probability (Rush et al. 2009; Conway and Gibbs 2011; Jacques et al. 2014). Genders may even have differing detection probabilities, such as in the willow flycatcher (*Empidonax traillii*) in Costa Rica where male flycatchers had a 13% higher detection probability (Koronkiewicz et al. 2006).

Despite the importance of detection probability to abundance estimates, 92% of landbird studies reviewed by Rosenstock et al. (2002) did not examine species detection rates. In addition, very few calculations of detection probability for marsh birds have been conducted (Conway and Gibbs 2001) and even fewer articles explored observer effects to detection (Conway and Simon 2003). We know of only one estimate of crane detection probability. Strobel and Butler (2014) documented whooping crane *(Grus americana)* detection probability as 0.558 (SE=0.031) within 500 m of aerial transects.

Several different methods may be used for estimation of population abundance and/or quantifying detection probability. Mark-recapture, N-mixture, and distance methods are used to calculate abundance for free-ranging wildlife (Royle 2004; Mills 2007; Huggins and Hwang 2011). The mark- recapture method uses capture histories from marked individuals on multiple sampling occasions to estimate the probability of detection and population size (Huggins 1989). This model assumes that all individuals behave independently (Huggins 1989). The N-mixture method of population estimation does not require individuals to be marked, but instead focuses on the history of sightings at individual survey sites (Royle 2004). Probability of detection each time a site is surveyed is assumed to follow a binomial distribution, and depends on the abundance at a site (Royle 2004). Maximum likelihood methods are then used to estimate abundance and detection probabilities at each site (Royle 2004). The distance model of population estimation uses sighting distances to create a maximum likelihood equation to estimate the number of individuals missed during a survey (Buckland et al. 1993).

To reduce bias, several long-term survey methods have recently changed to incorporate detection probabilities into population estimates (Conway 2011; Butler et al. 2014). For example, the standardized North American marsh bird monitoring protocol has recently been modified to allow for estimation of detection probability through the time of detection and distance methods (Conway 2011). In the same way, winter surveys of whooping cranes at Aransas National Wildlife Refuge in Texas have been updated to allow for integration of detection probability through the use of distance sampling (Stehn and Taylor 2008; Butler et al. 2014; Strobel and Butler 2014).

The need to identify a reliable means of counting and monitoring the eastern sandhill crane population has recently been identified as a priority by the US Fish and Wildlife Service (Kruse et al. 2010). The first objective of our study was to estimate the probability of detection for territorial and non-territorial greater sandhill cranes in Briggsville, Wisconsin. Our second objective was to estimate abundance of territorial and non-territorial sandhill cranes on breeding grounds in Briggsville, Wisconsin. We hypothesized that territorial and non-territorial cranes would have different probabilities of detection, because of different movement patterns (Su 2003). Movements of breeding and non-breeding sandhill cranes differ during the breeding season (Hayes and Barzen 2006). Breeding cranes have limited movements because of territoriality, while non-breeding cranes congregate and travel greater distances during the day (Miller 2002). Not accounting for different detection probabilities for these two social groups of cranes may bias population estimates from index counts on breeding grounds.

METHODS

Study Area

The study area is located northeast of Briggsville, Wisconsin, an unincorporated township in Marquette County, Wisconsin. The 6,600 ha site includes three large wetland areas (10 to 200 ha) with emergent vegetation, surrounding three local creeks (Su 2003). Smaller wetlands (< 10 ha) also are dispersed along the landscape (Su 2003). The wetlands are surrounded by agricultural fields, residential homes, grassland, and forest

(Su 2003; Hayes and Barzen 2006). Corn (*Zea mays*), alfalfa (*Medicago sativa*), and soybeans (*Glycine max*) are the most common crops (Su 2003).

Survey Methods

Biologists banded cranes as flightless chicks or by baiting cranes to a trap location using corn treated with the anesthetic alpha-chloralose (Hayes et al. 2003). Once restrained, biologists fitted cranes with a USGS metal band, a 7.62 cm plastic band displaying a unique, field visible number, and three colored, 2.54 cm plastic bands in a unique combination.

Sandhill cranes return to the Briggsville area to breed between March and April each year (Hayes and Barzen 2006). Surveys for this study began on April 3, 2009 and ended on June 16, 2009, and consisted of three circular routes (17.9km, 21.8km, and 24.5km) of public roads that surrounded three large wetland areas (Figure 1.1). Four technicians participated in observations during the field season. Technicians observed cranes on both sides of the road. On many sampling areas, residential housing or forestland obscured the view on one side of the route. As a result, the observers were often driving in a circle around a wetland complex for approximately 1 hour per survey. Technicians surveyed each route twice a week for a total of 67 surveys over 55 days of sampling (one route was surveyed one extra time). One survey day consisted of a technician driving the specified survey route six times. Surveys began approximately a half hour before sunrise at one of six randomly chosen starting points on the survey. Surveys ended at approximately a half hour after sunset. Technicians observed cranes from the roadside using binoculars or spotting scopes and recorded the color combination and/or field visible number of any marked crane, number of unmarked cranes, group size, and its relative position on printed aerial photos.

Data Analysis Methods

We used two methods to calculate estimates of detection probability and abundance of sandhill cranes. We began with the Huggins closed capture model in Program MARK in order to explore the possibility of heterogeneous detection probabilities within the population. We used survey data on banded cranes only in this part of our research. This guided the model set for subsequent analyses where we used survey data for all cranes, banded and unbanded, in order to estimate the abundance of each group of sandhill cranes in the study area.

Huggins Closed Capture Analysis

We used capture histories for marked cranes and the Huggins closed capture model in Program MARK (Huggins 1989; White and Burnham1999) to determine probability of detection per day and abundance estimates for marked territorial and non-territorial sandhill cranes. The Huggins model allowed us to model the effect of covariates on detection (Huggins 1989). Capture histories were created for each marked crane by treating each day as a capture event and pooling all six runs of a survey route. Thus, if a crane was sighted during any of the six runs in a day, it was recorded as a 1, and if it was not seen at all it was given a zero.

We identified the territorial status of all marked cranes and used this as a covariate in our analysis (TERRITORIALITY). Territorial cranes were identified as a pair of cranes occupying the same breeding and foraging area annually and/or displaying territorial behavior, such as low bows or ruffle bows directed at a conspecific (Tacha

1988). Cranes classified as territorial during the 2007-2008 breeding season and returning in the 2009 season paired with the same individual were considered territorial in 2009. Non-territorial cranes neither defend a territory nor display repeated aggressive behavior toward conspecifics at a specific location, and are most likely found in groups of 3 or more cranes (Su 2003). We used observation histories of marked individuals to separate observations into first detection and subsequent detections (DETECTION EVENT). This separation tested for the effect of observer bias on abundance estimates, which has been documented in other studies (Riddle et al. 2010). We hypothesized that after the initial detection of a crane, technicians would have a higher probability of redetecting the crane. We used ArcGIS® software (Esri, Redlands, California) to determine the distance from the survey road to an observed crane for each sighting. The average distance of the crane from survey road over the entire survey period was used in analysis (DISTANCE). We split observations into three intervals each spanning18 or 19 survey days in order to test the effect of time of season on detection probability (TIME OF SEASON). This corresponded to the dates April 3 – April 25, April 26 – May 22, and May 24 – June 16.

We tested nine *a priori* models containing these four covariates because we hypothesized that each covariate could affect detection probability (TERRITORIALITY, DETECTION EVENT, DISTANCE, and TIME OF SEASON.) We also tested a null model (.). We held abundance constant and allowed detection probability to differ based on covariates alone, and combinations of covariates. We used Akaike's Information Criterion (AIC; Burnham and Anderson 2002) for model selection. Because the number of cranes was small relative to the number of variables (K) in several models (i.e., $n/K < 40$), we used AIC corrected for small sample size (AIC_c) for model selection (Burnham and Anderson

2002). We drew primary inference from models within 2 units of AIC_{cmin}, although models within 4-7 units may have limited empirical support (Burnham and Anderson 2002).The raw data entered into Program MARK for this analysis is provided in Appendix A.

Royle N-mixture Analysis

After reviewing the results of the detection probability analysis on marked cranes in Program MARK, we used Royle's N-mixture method in Program PRESENCE to estimate abundance and detection probability per day for all cranes in the Briggsville study area. Sandhill cranes leave roosting sites at sunrise and return at sunset (Johnsgard 1983). Thus, we used the first round of surveys (out of the six completed daily) to reduce double counting.

We divided the study area into 106 sites, along the three aforementioned routes, for analysis (Figure 1.2). Forested areas and roads provided natural partitions for most sites. The shape of surveyed roads allowed a technician to observe the site from multiple locations. If the technician had to drive a substantial distance in order to accurately count or identify cranes, the area was separated into two sites. We obtained the size of each site using ArcMAP® software (Esri, Redlands, California) (SIZE), and also assigned the site to a broad habitat category of upland or wetland (HABITAT). We hypothesized that the cranes with an unknown territorial status (hereafter called unbanded cranes) were most likely composed of non-territorial cranes. To test this hypothesis, we divided observed cranes into groups using two different approaches. The first approach divided observed cranes into three categories; banded territorial, banded non-territorial, and unknown (BIRD STATUS). The second approach divided observed cranes into two categories;

banded territorial and other, which was the combination of banded non-territorial cranes and unknown cranes (TERR VS. OTHER). We chose a crane's status of territorial or non-territorial as described above, and all unbanded birds were placed in the unknown category. First and subsequent detections were shown to have a large influence on detection probability in the Huggins closed capture analysis, thus we included a covariate to account for an observer effect (OBSERVER). In this model, an observer effect would be at the site level. As opposed to the Huggins model, in which an increase in detection was expected for a specific crane, in the N-mixture model, an increase in detection was expected for a specific site. For this model, we hypothesized that after an initial detection at a site the probability of detecting one or more cranes at the same site on a subsequent survey would increase.

We used Program PRESENCE 6.5 (Hines 2006) to model detection probability and abundance in sandhill cranes. We constructed 25 *a priori* models using 5 covariates: SIZE, HABITAT, BIRD STATUS, TERR VS. OTHER, and OBSERVER. Abundance was allowed to vary by 3 covariates: BIRD STATUS, TERR VS. OTHER, and SIZE, as well as a combination of SIZE and BIRD STATUS. Detection probability was allowed to vary by 4 covariates: BIRD STATUS, TERR VS. OTHER, HABITAT, and OBSERVER as well as combinations of these covariates. The distribution of cranes over survey sites was assumed to follow a Poisson distribution.

Ad Hoc Analysis

We observed that unbanded cranes in the N-mixture analysis were detected at the same rate as non-territorial cranes in the Huggins analysis. As a result, we conducted two ad hoc analyses. Ad hoc analysis 1 assumed all observed unbanded cranes were non-territorial, and ad hoc analysis 2 assumed that half of the observed unbanded cranes were territorial and half were non-territorial. We used the detection probabilities of non-territorial and territorial cranes from the Huggins method ($\hat{p}$ = 0.3 non-territorial, $\hat{p}$ =0.11 territorial) to adjust the raw counts of unbanded cranes. Each site was observed 22 or 23 times over 55 days. We divided the number of unbanded cranes seen on each day at each site by a detection probability of 0.3 or 0.11 depending on analysis. Next, we averaged the detection-corrected count of cranes seen at each site over the survey period. The average number of cranes for each site was summed to calculate an abundance estimate for cranes of unknown territorial status.

RESULTS

Results from Huggins Closed Capture Analysis

During surveys in 2009, we observed 52 uniquely banded territorial sandhill cranes and 23 uniquely banded non-territorial sandhill cranes. TERRITORIAL STATUS + CAPTURE EVENT best explained detection probability for sandhill cranes (Table 1.1). This model had an Akaike weight of 0.92. The second best model also included TERRITORIAL STATUS and CAPTURE EVENT with the addition of a TIME OF SEASON variable. However, this model was 4.97 delta AIC_c units from the first, which gives the model little support (Burnham and Anderson 2002). TIME OF SEASON alone was the lowest ranking model with a delta AIC_c of 82.95. DISTANCE from transect line was shown to have little influence over detection with a delta AIC_c of 69.8. The population estimate for territorial sandhill cranes derived from the best model was 52.11 (SE = 0.35), and for non-territorial cranes was 27.51 (SE = 4.81) (Table 1.2).

We calculated detection probabilities for both social groups of cranes as well as for first and subsequent capture events (Table 1.3). The detection probability upon first detection, for territorial sandhill cranes ($\hat{p}$ = 0.11; SE = 0.01) was three times higher than for non-territorial sandhill cranes ($\hat{p}$ = 0.03; SE = 0.01). In addition, detection probabilities for both social groups increased after the initial detection (Table 1.3). Territorial sandhill cranes were 1.5 times more likely to be detected after an initial sighting ($\hat{p}$ = 0.18; SE = 0.01), and non-territorial cranes were more than 3 times more likely to be detected after an initial sighting ($\hat{p}$= 0.11; SE = 0.01).

Results from Royle N-mixture Analysis

Our best approximating model showed that site SIZE and BIRD STATUS were important covariates for abundance and BIRD STATUS alone best modeled detection probability (Table 1.4). The model with the second most support included (TERR VS OTHER) as the single factor influencing detection probability, but this model was 11.12 delta AIC_c units from the top model. The population estimate from the best model was 75.19 (SE =10.26) for territorial sandhill cranes, 24.88 (SE = 6.45) for non-territorial cranes and 4,051.28 (SE = 25.85) for unbanded cranes (Table 1.5). We estimated detection probability for territorial cranes as 0.12 (SE = 0.011), for non-territorial cranes as 0.08 (SE = 0.0168), and for unbanded cranes as 0.0259 (SE = 0.0007) (Table 1.6).

Results from Ad-Hoc Analysis

For Ad Hoc Analysis 1, using the assumption that all unbanded cranes observed during the survey were non-territorial with a detection probability of 0.03, the total abundance estimate for unbanded cranes was 3005.71 (SE = 1269.55) (Table 1.7). For Ad Hoc Analysis 2, using the assumption that half of the unbanded cranes observed during the survey were territorial and the other half non-territorial with a detection probability of 0.11 and 0.03 respectively, the abundance estimate for unbanded territorial cranes was 353.85 (SE = 149.46) and for unbanded non-territorial cranes was 1297.46 (SE = 548.024) (Table 1.7).

DISCUSSION

The two methods used to quantify detection probability of sandhill cranes provided similar estimates for both territorial as well as non-territorial cranes, giving us confidence in the precision of the results (Table 1.8). The Huggins method was more precise with smaller confidence intervals than the N-mixture method. In addition, detection estimates from the N-mixture method for banded territorial and non-territorial cranes were approximately midway between first and subsequent detection estimates from the Huggins method, which is likely because the N-mixture method does not identify individuals, and cannot distinguish between first and subsequent detections of individual cranes.

Our detection probabilities for sandhill cranes are much lower than the documented detection probability of whooping cranes during aerial surveys at Aransas NWR, 0.558 (SE=0.031) (Strobel and Butler 2014). This may be due to the conspicuous white plumage of whooping cranes or because the survey was done from aircraft. Low detection probabilities may occur because observers are driving during the survey and must watch both the road and look for cranes at the same time. Also, we did not actively sample with calling surveys. The plumage of sandhill cranes is cryptic, and blends in well with a background of corn fields. Although detection probability of cranes per day was low, the number of surveys conducted (55) was sufficient to detect 99% of territorial cranes and 84% of non-territorial cranes.

Territorial status is an important variable to consider when surveying sandhill cranes in Briggsville, Wisconsin during the breeding season. Of the models we prepared *a priori*, overwhelming support for the models containing territorial status supports our hypothesis that territorial and non-territorial cranes are detected differently on the breeding grounds. We recognize that factors not identified by our analysis also may affect detection probability of sandhill cranes. The N-mixture method identified BIRDS STATUS (territorial, non-territorial, and unbanded) as the single most explanatory variable for detection probability. Lack of support for the model containing the variable TERR VS OTHER, which split observed cranes into two groups instead of three, emphasizes the importance of territorial status and banding to detection probability and that detection probability for our population is best described when split into three groups, territorial, non-territorial, and unknown.

Both methods revealed that territorial cranes were more likely to be detected on any given day than non-territorial cranes. We speculate that territorial cranes may be more conspicuous because their movement patterns on the breeding grounds are more restricted than non-territorial cranes. Miller (2002) conducted research on the Briggsville study site and determined that the home range size for breeding sandhill cranes varied over the breeding season with a mean of 284.7ha ± 59.7 (n=12). Su (2003), again working on the Briggsville study site, states that the average daily distance traveled from the roost was 300m for territorial sandhill cranes and 3,000m for non-territorial cranes. Melvin (1978) documented home ranges of non-breeding sandhill cranes in southern

Wisconsin as 774 to 3,691ha (n=58). Additionally, cranes show smaller home ranges as they mature. Home range size of first year sandhill cranes was calculated as 197.3 km^2 (SE 85.71 n=30), second year cranes was 54.03 km^2 (SE 10.81 n= 15), and third year cranes was 28.26 km^2 (SE 10.65 n=7) using 95% kernel analyses (Hayes unpublished data). The Florida sandhill crane subspecies also illustrates a difference in movement and home range size by social group with territorial adults and sub-adults (assumed non-territorial) possessing home range sizes of 447ha and 2,132 ha, respectively (Nesbitt and Williams 1990). The smaller home range and shorter daily movements from nest or roost site to foraging site of territorial cranes may explain the higher detection rate of this social group. Restricted movement of territorial cranes may cause them to be present more often within the survey area and thus more available for detection.

The use of individual detection histories in the Huggins model revealed that detection probabilities for both social groups increased significantly with subsequent capture events. The Huggins closed capture model identified both TERRITORIALITY and CAPTURE EVENT as contributing to detection probability. Territorial cranes were 1.5 more likely to be detected after the initial sighting and non-territorial cranes were more than 3 times more likely to be detected after the initial sighting. Aspects of bird or observer behavior could account for an increase in detection probability after an initial detection. For instance, observers may learn where to look for birds over time or birds may begin to use the same fields over time. The effect of observer bias on abundance estimates has been documented (Riddle et al. 2010). Even when following acceptable methods for surveys, unforeseen biases in detection can affect survey results. Conn et al. (2006) emphasized the influence of individual heterogeneity on abundance estimates. Giudice et al. (2013) found that models of detection probability for ring-necked pheasants (*Phasianus colchicus)* revealed the importance of environmental factors (background noise, temperature, etc.) on detectability even though generally accepted survey methods were employed. Thompson (2002) stated that standardizing survey protocols alone does not account for all bias in surveys. Our survey applied many conventional methods in order to decrease survey bias, such as random starting points. However, our results show that a substantial bias in detection still existed. This substantial increase in detection was evident in the Huggins model, but an observer effect on detection probability had very little support in the N-mixture analysis. The Huggins closed capture model uses detection histories from known individuals while the N-mixture model does not identify individuals. This is most likely the reason an observer effect was noticed in the Huggins analysis and not the N-mixture analysis.

Our goal was to estimate abundance for both the territorial and non-territorial factions of the Briggsville sandhill crane population. The abundance estimate for unbanded cranes derived from the N-mixture method was 4,051.28 (SE = 25.85) (Table 1.5). This number was calculated by summing the abundance estimates for unbanded cranes for each site on the survey route. However, some site specific estimates for unbanded cranes were not biologically likely (Barzen, personal communication), with estimates in the range of 69-744 cranes. The sites with the largest estimates for unbanded cranes were large in size (> 60.7 ha), and many had at least one sighting of a large group of unbanded cranes (20-70 cranes). The N-mixture model is different than other models used to calculate abundance because it takes into account three components of detection; presence, availability, and detection given availability (Nichols et al. 2009). Specifically, detection probability estimates from N-mixture models are the product of all three components (Nichols et al. 2009). Therefore, detection probabilities from this method tend to be lower than those from other methods, and abundance estimates will tend to be higher (Nichols et al. 2009). In addition, the N-mixture model abundance estimate is actually a "superpopulation" estimate that includes all cranes with potentially overlapping home ranges because it accounts for the presence component of detection (Nichols et al. 2009). Sites with unrealistically high abundance estimates may be highly favored foraging areas, within the home ranges of many sandhill cranes. If sites are small compared to home range sizes, and few home ranges overlap more than one site, than the abundance estimate for each site summed together may be an overestimate due to double-counting. Non-territorial cranes have larger home ranges and travel farther from roost sites each day than territorial cranes (Miller 2002; Su 2003; Hayes unpublished data). Thus, abundance estimates calculated using the N-mixture method for territorial cranes are likely to be more precise and reliable than those for non-territorial cranes. However, since not all cranes are banded we could not place all observed cranes into these two categories.

The unlikely population estimate produced by the N-mixture model for the population of unbanded cranes in Briggsville prompted us to use two ad hoc estimation methods to calculate abundance for this group. The entire population of unbanded cranes is likely comprised of both territorial and non-territorial individuals. Not all territorial cranes on the study site are banded (ICF, unpublished data). However, the detection probability estimate for cranes with unknown territorial status using the N-mixture method ($\hat{p}$ = 0.0259) was almost exactly the same as the estimate for non-territorial crane detection probability in the Huggin's method ($\hat{p}$ = 0.03), indicating that cranes with unknown territorial status are detected in a similar way as non-territorial cranes. We have no way of definitively identifying whether unbanded cranes are territorial or non-territorial, because individuals cannot be observed. We believe our ad hoc estimates to be more realistic estimates for unbanded cranes than the estimate generated by N-mixture models.

Although the EP of sandhill cranes is not threatened, it will be important for wildlife managers to monitor the reaction of this population to recently introduced hunting pressure (Kruse et al. 2013). Managers should take detection probability into consideration when deciding on survey methods to monitor crane species (Conway and Simon 2003). A census of the sandhill population is not feasible, so survey methods that incorporate detection probability estimates may be valuable to wildlife managers who wish to monitor cranes. Currently, the eastern population of sandhill cranes is counted during fall migration. Detection probability may not be as divergent between social groups during migration, because the cranes are less territorial during this time of year (Johnsgard 1983). However, trends in migration surveys may be hard to detect due to the influence of weather on the number of birds using a particular stopover site (Dunn and Hussell 1995, Ralph et al. 1995). Surveys at breeding grounds may be more informative, but we found that differential detection between crane social groups was a significant factor to consider before choosing this option. Some researchers argue that detection estimates for large surveys are impractical and that indices are still useful (Johnson 2008). If individual cranes cannot be marked, or if specific covariates affecting detection probability cannot be identified, indices may be the only option for population monitoring. However, an index count of a population may be misleading if detection probability is not consistent over time. The N-mixture method does not require a marked population, but we found that estimates from this method may be high for non-territorial cranes due to large home ranges. We have shown that detection probability for sandhill cranes on a breeding ground is low, and is an important factor when estimating crane abundance.

Crane species worldwide are threatened with low populations and loss of wetland habitat which makes estimates of crane breeding populations of paramount importance. Determining appropriate methods to evaluate abundance on breeding grounds are warranted for imperiled crane species. Sandhill cranes, with a worldwide population estimated at 700,000 (Meine and Archibald 1996) is not a threatened species, but insights into detectability of sandhill crane social groups may provide useful insights into detection of other crane species.

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Figure 1.1 In 2009, three survey routes were used to locate sandhill cranes in Briggsville, Wisconsin.

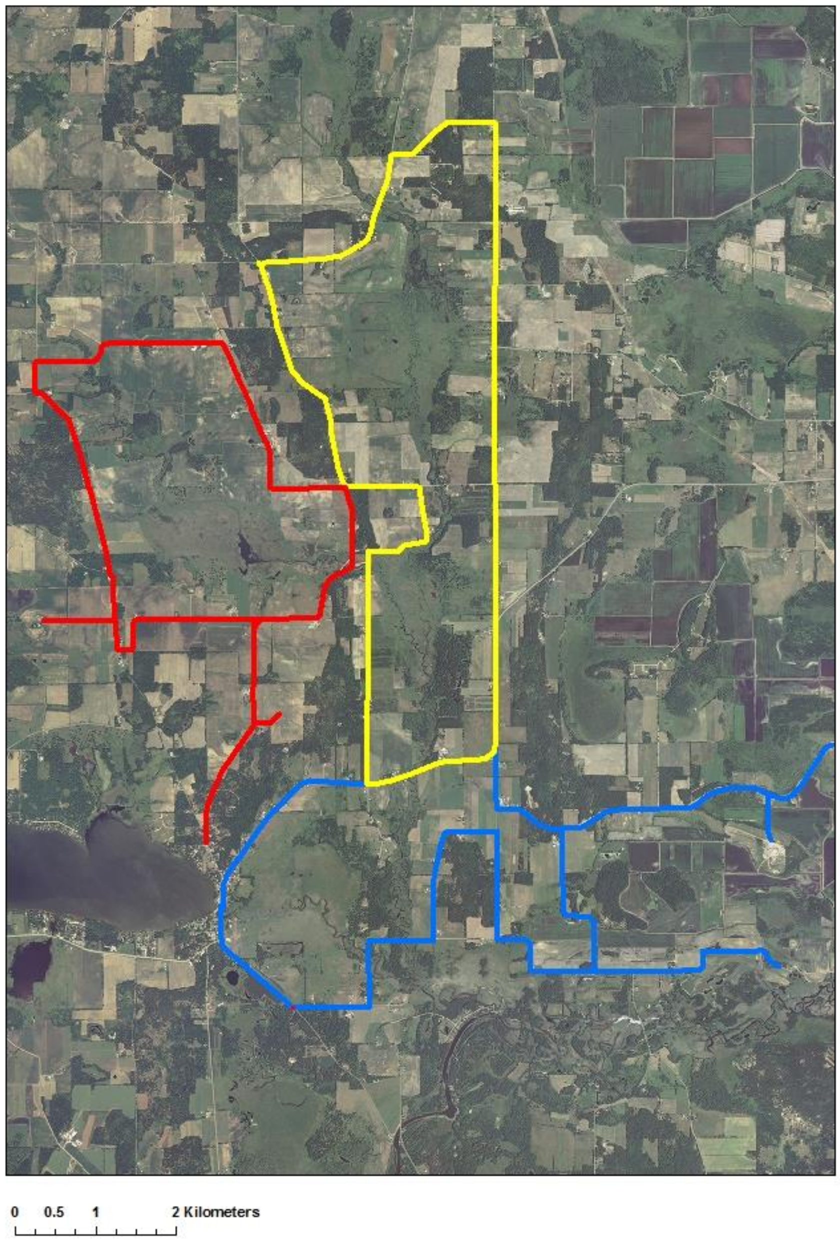

Figure 1.2. Survey routes in Briggsville, Wisconsin divided into 106 sites for Royle N-mixture analysis.

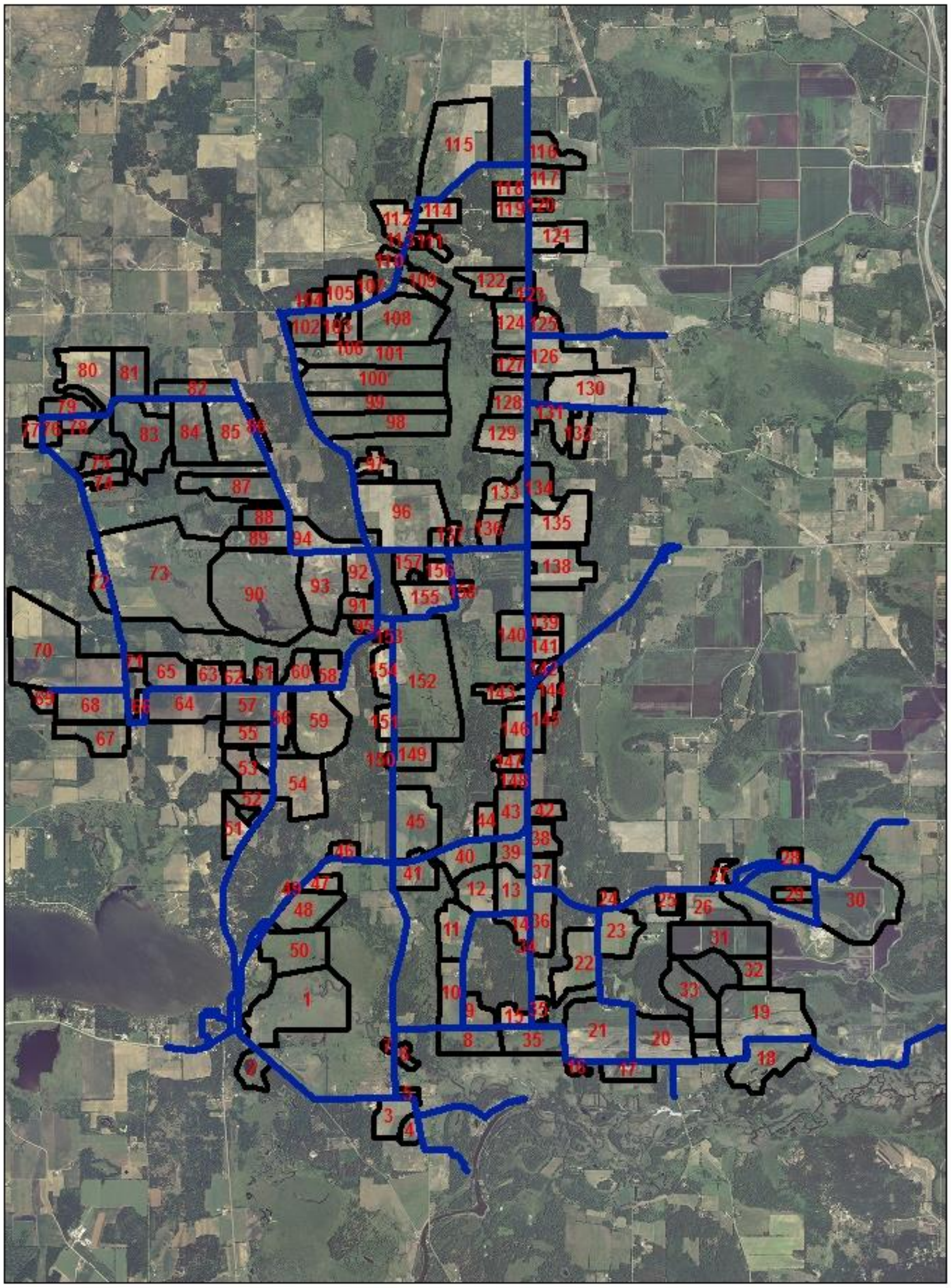

Table 1.1. Akaike's Information Criterion adjusted for small sample size model selection of Huggins closed capture models for sandhill cranes in Briggsville, WI, 2009.

Model	**K**[a]	**AICc**[b]	**Δ AICc**[c]	**AICc Weight**[d]	**Model Likelihood**
Territorial status, Detection Event	4	3358.7	0	0.92	1
Time of Season, Territoriality, Detection Event	12	3363.7	4.97	0.08	0.0831
Time of Season, Detection Event	6	3388	29.33	0	0
Detection Event	2	3390.9	32.18	0	0
Territoriality	2	3394.2	35.49	0	0
Time of Season, Territoriality	6	3397.9	39.26	0	0
Distance	2	3428.5	69.8	0	0
Null	1	3441.3	82.59	0	0
Time of Season	3	3441.6	82.95	0	0

[a] Number of Parameters

[b] Akaike's Information Criterion corrected for small sample size

[c] Difference in AIC_c relative to minimum AIC_c

[d] Akaike weight

Table 1.2. Population estimate for two social groups of sandhill cranes, from the best approximating model in the set evaluated for sandhill crane detection probability in Briggsville, WI 2009 using the Huggins closed capture model.

Group	**β**[a]	**SE**[b]	**95% CI**[c]
Territorial	52.11	0.35	52.01 - 54.30
Non Territorial	27.51	4.81	23.82 - 47.87

[a] Population estimate

[b] Standard Error

[c] Confidence Interval

Table 1.3 Huggins closed capture analysis in Program MARK of territorial status and capture event on detection probability of banded sandhill cranes in Briggsville, WI, 2009.

Group	**Capture Event**	$\hat{p}$ [a]	**SE**[b]	**95% CI**[c]
Territorial	First	0.11	0.01	0.08 - 0.14
Territorial	Subsequent	0.18	0.01	0.17 - 0.20
Non-territorial	First	0.03	0.01	0.01 - 0.07
Non-territorial	Subsequent	0.11	0.01	0.09 - 0.14

[a] Detection probability

[b] Standard Error

[c] Confidence Interval

Table 1.4. Akaike's Information Criterion model selection of Royle N-mixture models for sandhill cranes in Briggsville, WI, 2009.

Model	**K**[c]	**AIC$_c$**[d]	**ΔAIC**[e]	**AIC$_c$ wgt**[f]	**Model Likelihood**
λ[a] (SIZE + BIRD STATUS) $\hat{p}$[b] (BIRD STATUS)	7	8443.05	0	0.9962	1
λ (SIZE + BIRD STATUS) $\hat{p}$ (TERR VS. OTHER)	6	8454.17	11.12	0.0038	0.0038
λ (SIZE + TERR VS. OTHER) $\hat{p}$ (BIRD STATUS)	6	8480.39	37.34	0	0
λ (SIZE + BIRD STATUS) $\hat{p}$ (HABITAT)	6	8516.15	73.1	0	0
λ (SIZE + BIRD STATUS) $\hat{p}$ (OBSERVER)	6	8622.9	179.85	0	0
λ (SIZE) $\hat{p}$ (BIRD STATUS)	5	8873.64	430.59	0	0
λ (BIRD STATUS) $\hat{p}$ (TERR VS. OTHER)	5	9374.48	931.43	0	0
λ (BIRD STATUS) $\hat{p}$ (BIRD STATUS)	6	9375.51	932.46	0	0
λ (TERR VS. OTHER) $\hat{p}$ (BIRD STATUS)	5	9432.91	989.86	0	0
λ (.) $\hat{p}$ (BIRD STATUS)	4	9681.83	1238.78	0	0
λ (SIZE + TERR VS. OTHER) $\hat{p}$ (OBSERVER)	5	9687.51	1244.46	0	0
λ (SIZE + TERR VS. OTHER) $\hat{p}$ (TERR VS. OTHER)	5	9734.1	1291.05	0	0
λ (SIZE + TERR VS. OTHER) $\hat{p}$ (HABITAT)	5	9745.13	1302.08	0	0
λ (SIZE) $\hat{p}$ (TERR VS. OTHER)	4	9891.59	1448.54	0	0
λ (SIZE) $\hat{p}$ (OBSERVER)	4	9995.32	1552.27	0	0
λ (SIZE) $\hat{p}$ (HABITAT)	4	10050.19	1607.14	0	0
λ (BIRD STATUS) $\hat{p}$ (OBSERVER)	5	10068.83	1625.78	0	0
λ (TERR VS. OTHER) $\hat{p}$ (OBSERVER)	4	10307.04	1863.99	0	0
λ (TERR VS. OTHER) $\hat{p}$ (HABITAT)	4	10388.75	1945.7	0	0
λ (TERR VS. OTHER) $\hat{p}$ (TERR VS. OTHER)	4	10402.64	1959.59	0	0
λ (.) $\hat{p}$ (OBSERVER)	3	10557.84	2114.79	0	0
λ (.) $\hat{p}$ (TERR VS. OTHER)	3	10572.25	2129.2	0	0
λ (.) $\hat{p}$ (HABITAT)	3	10683.08	2240.03	0	0
λ (.) $\hat{p}$ (.)	2	10706.01	2262.96	0	0
λ (BIRD STATUS) $\hat{p}$ (HABITAT)	5	11815.02	3371.97	0	0

[a] Abundance

[b] Detection Probability

[c] Number of Parameters

[d] Akaike's Information Criterion corrected for small sample size

[e] Difference in AIC$_c$ relative to minimum AIC$_c$

[f] Akaike weight

Table 1.5. Population estimate for sandhill cranes, from the best approximating model in the set evaluated by Program PRESENCE for sandhill crane in Briggsville, WI 2009.

Group	**β[a]**	**SE[b]**	**95% CI[c]**
Territorial	75.19	10.2625	57.54 - 98.25
Non-territorial	24.88	6.4495	14.97 - 41.35
Unknown	4051.28	25.8465	4001.06 -4102.38

[a] Population estimate

[b] Standard Error

[c] Confidence Interval

Table 1.6. Program PRESENCE, Royle N-Mixture model, estimated detection probabilities for three groups of sandhill cranes in Briggsville, WI, 2009.

Group	$\hat{p}$ [a]	**SE** [b]	**95% CI** [c]
Territorial	0.1157	0.0115	0.095 - 0.1402
Non Territorial	0.0761	0.0168	0.049 - 0.1163
Unknown	0.0259	0.0007	0.0245 - 0.0274

[a] Detection probability

[b] Standard Error

[c] Confidence Interval

Table 1.7. Results of Ad Hoc Analyses 1 &2. Ad Hoc Analysis 1 assumed all unbanded cranes were non-territorial. Ad Hoc Analysis 2 assumed half of the unbanded cranes were territorial and half were non-territorial.

Group	Ad Hoc Analysis 1	Ad Hoc Analysis 2	N-mixture model
Unbanded Territorial	N/A	353.85 (60.91 – 646.80)	N/A
Unbanded Non-territorial	3,005.71 (517.38–5,494.03)	1,297.46 (223.34–2,371.59)	N/A
Total unbanded population	3,005.71 (517.38–5,494.03)	1,651.31 (284.25 – 3,018.39)	4,051.28 (4,001.06 - 4,102.38)

Table 1.8. Comparison of detectability estimates for social groups of sandhill cranes from Huggins closed capture model in Program MARK and N-mixture model in Program PRESENCE.

Group	Huggins	N-mixture
Territorial First Capture	0.11 (0.08-0.14)	0.12 (0.10-0.14)[2]
Territorial Subsequent Capture	0.18 (0.17 - 0.20)	N/A[2]
Non-Territorial First Capture	0.03 (0.01 - 0.07)	0.076 (0.049-0.12)[2]
Non-Territorial Subsequent Capture	0.11(0.09-0.14)	N/A[2]
Unknown territorial status (unbanded)	N/A[1]	0.0259 (0.0245 - 0.0274)

[1] Only banded cranes were used in the Huggins closed capture model

[2] No differentiation between first and subsequent captures of individual cranes in the N-mixture model

Table 1.9. Comparison of population estimates and 95% confidence intervals of sandhill cranes in Briggsville, Wisconsin calculated using the Huggins closed capture model in Program MARK and the N-mixture model in Program PRESENCE.

Group	Huggins	N-mixture
Territorial	52.11 (52.01–54.30)	75.19 (57.54-98.25)
Non-territorial	27.51 (23.82-47.87)	24.88 (14.97-41.35)
Unknown (Unbanded)	N/A[a]	4051.28 (4001.06-4102.38)

[a] No estimate

Appendix A. Raw data from Program MARK analysis.

Bird Id Number	4/3/2009	4/4/2009	4/5/2009	4/6/2009	4/7/2009	4/8/2009	4/10/2009
55961710	0	0	0	0	0	0	0
62922106	1	0	0	0	0	0	0
62922116	0	0	0	0	0	0	0
62922117	0	0	0	0	0	0	0
62922126	0	0	0	0	0	0	0
62922134	1	0	1	0	0	1	0
62922139	1	0	1	0	0	0	0
62922140	1	0	0	0	0	0	0
62922150	0	0	0	0	0	0	0
62922160	0	0	0	0	1	0	0
62922162	1	0	1	0	0	1	0
62922163	1	0	1	0	0	0	0
62922178	1	0	0	0	0	0	0
62922179	0	0	0	0	0	0	0
62922184	1	0	0	0	0	0	0
62923420	0	0	0	0	0	0	0
62923427	0	0	0	1	0	0	0
62923435	1	0	0	0	0	0	0
62923439	0	1	0	0	0	0	0
62923448	1	0	0	0	0	0	0
62923452	0	0	0	0	0	0	0
62923460	0	0	0	0	0	0	0
62923463	0	1	0	1	0	0	0
62923477	1	0	0	0	0	0	0
62923487	1	0	1	0	0	1	0
62923490	0	0	0	0	0	0	0
62923491	1	0	0	0	0	0	0
62923492	1	0	0	0	0	0	1
62938723	1	0	1	0	0	0	0
62938724	0	0	1	0	0	0	0
62945201	1	0	1	0	0	1	0
62945202	1	0	1	0	0	1	0
62945211	0	0	0	0	0	0	0
62945214	1	0	0	0	0	0	0
62945217	1	0	0	0	0	0	0
62945221	0	0	0	0	0	0	0
62945222	1	0	1	0	0	1	0
62945223	0	0	0	0	0	0	0
62945227	0	0	0	0	0	0	0

62945231	1	0	1	0	0	1	0
62945232	1	0	0	0	0	0	1
62945234	1	0	0	0	0	0	0
62945236	1	0	1	0	0	1	0
62945239	1	0	0	0	0	1	0
62945244	0	0	0	0	0	0	0
62945247	1	0	1	0	0	0	0
62945250	0	0	0	0	0	0	0
62947256	0	0	0	0	0	0	0
62947257	0	0	0	0	0	0	0
62947258	0	0	0	0	0	0	0
62947259	1	0	1	0	0	0	0
62947260	0	0	0	0	1	0	0
62947261	0	0	0	0	0	0	0
62947262	0	0	0	0	0	0	0
62947263	0	1	0	1	0	0	0
62947264	0	0	1	0	0	1	0
62947265	0	0	1	0	0	1	0
62947267	0	1	0	0	0	0	0
62947268	1	0	0	0	0	0	0
62947269	1	0	0	0	0	0	0
62947273	0	0	0	0	0	0	0
62947275	0	0	0	0	0	0	0
62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	0	0	0	0	0
62947281	0	0	0	0	0	0	0
62947283	0	0	0	0	0	0	0
62947285	0	0	0	0	0	0	0
62947286	0	0	0	0	0	0	0
62947287	0	0	0	0	0	0	0
62947289	0	0	0	0	0	0	0
62947290	0	0	0	0	0	0	0
62947292	1	0	1	0	0	0	0
62947293	0	0	0	0	0	0	0
62947297	0	0	0	1	0	0	0

Bird Id Number	4/11/2009	4/12/2009	4/13/2009	4/14/2009	4/15/2009	4/18/2009	4/20/2009
55961710	0	1	0	0	1	0	0
62922106	0	0	0	0	1	0	1
62922116	0	0	0	1	0	0	1
62922117	0	0	0	0	0	0	0
62922126	0	0	0	0	0	0	0
62922134	0	0	0	0	1	0	0
62922139	0	0	0	0	0	0	1
62922140	0	0	0	0	0	0	0
62922150	0	0	0	0	0	0	1
62922160	0	0	0	0	0	0	0
62922162	0	1	0	0	0	0	1
62922163	0	1	0	0	1	1	1
62922178	0	0	0	0	0	0	0
62922179	0	1	0	0	1	0	1
62922184	0	0	0	0	0	0	0
62923420	0	0	0	0	0	0	0
62923427	0	0	0	0	1	0	1
62923435	0	0	0	0	0	0	0
62923439	0	0	0	0	0	0	1
62923448	0	1	0	0	1	0	0
62923452	0	0	1	0	1	0	0
62923460	0	0	0	0	0	0	0
62923463	1	0	0	1	0	1	0
62923477	0	1	0	0	1	0	1
62923487	0	1	0	0	0	0	1
62923490	0	0	0	0	0	0	0
62923491	0	0	1	0	0	0	0
62923492	0	0	1	0	0	0	0
62938723	0	0	0	0	1	0	1
62938724	0	0	0	0	1	0	1
62945201	0	0	0	0	0	0	1
62945202	0	1	0	0	1	0	0
62945211	0	0	0	0	0	0	0
62945214	0	0	0	0	1	0	0
62945217	0	1	0	0	1	0	1
62945221	0	0	0	0	0	0	0
62945222	0	1	0	0	0	0	0
62945223	0	0	0	0	0	0	0
62945227	0	0	0	0	1	0	0
62945231	0	0	0	0	0	0	0
62945232	0	0	0	0	1	0	0

62945234	0	0	0	0	0	0	0
62945236	0	1	0	0	1	0	1
62945239	0	1	0	0	0	0	1
62945244	0	0	0	0	0	0	0
62945247	0	0	0	0	0	0	0
62945250	0	0	0	0	0	0	1
62947256	0	0	0	0	0	0	1
62947257	0	0	0	0	0	0	0
62947258	0	0	0	0	1	0	0
62947259	0	0	0	0	0	0	1
62947260	0	0	0	0	1	0	0
62947261	0	0	0	1	0	0	0
62947262	0	0	0	0	0	0	0
62947263	0	0	0	0	0	0	1
62947264	0	1	0	0	1	0	1
62947265	0	0	0	0	1	0	1
62947267	0	0	0	0	0	0	0
62947268	0	0	0	0	0	0	0
62947269	0	0	0	0	0	0	0
62947273	0	0	0	0	0	0	0
62947275	0	0	0	0	0	0	1
62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	0	0	0	0	0
62947281	0	0	0	0	0	0	0
62947283	0	0	0	0	0	0	0
62947285	0	0	0	0	0	0	0
62947286	0	0	0	0	0	0	0
62947287	0	0	0	0	0	0	0
62947289	0	0	0	0	0	0	0
62947290	0	0	0	0	0	0	0
62947292	0	1	0	0	0	0	1
62947293	0	0	0	0	0	0	0
62947297	0	0	0	0	0	0	1

Bird Id Number	4/21/2009	4/22/2009	4/24/2009	4/25/2009	4/26/2009	4/27/2009	4/29/2009
55961710	0	0	0	0	0	0	0
62922106	0	1	0	0	1	0	0
62922116	1	0	0	1	0	0	0
62922117	0	0	0	0	0	0	0
62922126	0	0	0	1	0	0	0
62922134	0	1	0	0	1	1	0
62922139	0	0	0	1	0	1	0
62922140	0	0	0	0	0	1	0
62922150	0	0	0	0	0	0	0
62922160	0	0	0	0	0	0	0
62922162	0	0	0	0	1	0	0
62922163	0	1	1	0	1	1	1
62922178	0	0	0	0	0	0	0
62922179	0	0	0	0	1	0	0
62922184	0	1	0	0	0	0	0
62923420	0	0	0	0	0	0	0
62923427	1	0	0	0	1	1	1
62923435	0	0	0	0	0	0	0
62923439	0	0	0	1	0	1	0
62923448	0	1	0	0	1	0	0
62923452	0	0	0	0	0	1	0
62923460	0	0	0	0	0	0	1
62923463	0	0	0	1	0	0	0
62923477	0	1	0	0	1	0	0
62923487	0	0	0	0	0	0	0
62923490	0	0	0	0	1	0	0
62923491	0	0	0	0	0	0	1
62923492	0	0	0	0	0	0	1
62938723	0	1	0	0	0	0	0
62938724	0	1	0	0	0	0	0
62945201	0	0	0	0	1	0	0
62945202	0	1	0	0	1	0	0
62945211	0	0	0	0	0	0	0
62945214	0	0	0	0	0	0	0
62945217	0	1	0	0	1	0	0
62945221	0	0	0	0	0	0	0
62945222	0	0	0	0	0	0	0
62945223	0	0	0	0	0	0	0
62945227	0	0	0	0	0	0	0
62945231	0	0	0	0	0	0	0
62945232	0	0	0	0	1	0	0

62945234	0	0	0	0	0	0	0
62945236	0	1	0	0	1	0	0
62945239	0	1	0	0	1	0	0
62945244	0	0	0	0	0	0	0
62945247	0	0	0	0	0	0	0
62945250	0	0	0	0	0	0	0
62947256	0	0	0	0	0	0	0
62947257	0	0	0	0	0	0	0
62947258	0	0	1	0	0	0	0
62947259	1	1	0	1	1	0	1
62947260	0	0	0	0	0	1	0
62947261	0	0	0	0	0	0	0
62947262	0	0	0	0	0	0	0
62947263	0	0	0	0	0	1	1
62947264	0	1	0	0	1	0	0
62947265	0	1	0	0	1	0	0
62947267	0	0	0	1	0	1	0
62947268	0	1	1	0	1	0	0
62947269	0	0	0	0	0	0	0
62947273	0	0	0	0	0	0	0
62947275	0	0	0	0	0	0	0
62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	0	0	0	0	0
62947281	0	0	0	0	0	0	0
62947283	0	0	0	0	1	0	0
62947285	0	0	0	0	0	0	0
62947286	0	0	0	0	0	0	0
62947287	0	0	0	0	0	0	0
62947289	0	0	0	0	0	0	1
62947290	0	0	0	0	0	0	0
62947292	0	1	0	0	1	0	0
62947293	0	0	0	0	0	0	0
62947297	0	0	0	0	0	1	1

Bird Id Number	5/1/2009	5/4/2009	5/5/2009	5/6/2009	5/8/2009	5/9/2009	5/10/2009
55961710	0	1	0	0	1	0	1
62922106	1	0	0	0	0	0	0
62922116	0	0	1	0	0	0	0
62922117	0	0	0	0	0	0	0
62922126	0	0	1	0	0	1	0
62922134	0	0	0	1	1	0	0
62922139	0	1	0	0	0	0	0
62922140	0	0	0	0	0	0	0
62922150	0	0	0	0	0	0	0
62922160	0	0	0	0	0	0	0
62922162	0	0	0	0	1	0	1
62922163	0	0	0	0	1	0	1
62922178	0	0	0	0	0	0	0
62922179	0	1	0	0	0	1	1
62922184	0	0	1	0	1	0	1
62923420	0	0	0	0	0	0	0
62923427	0	0	1	0	0	0	0
62923435	0	0	0	0	1	0	1
62923439	0	0	0	0	0	0	0
62923448	0	0	0	0	0	0	0
62923452	0	0	0	0	0	1	0
62923460	0	0	0	0	0	0	0
62923463	0	1	0	1	0	0	0
62923477	1	0	0	0	0	0	0
62923487	0	1	0	0	0	0	0
62923490	1	0	0	0	0	0	0
62923491	0	0	0	0	0	1	0
62923492	0	0	1	0	0	1	0
62938723	1	1	0	0	0	0	1
62938724	0	1	0	0	0	0	1
62945201	0	0	0	0	0	0	0
62945202	1	1	0	0	1	0	1
62945211	0	0	0	0	0	0	0
62945214	1	0	1	0	0	1	0
62945217	0	0	0	0	1	0	1
62945221	0	0	0	0	0	0	0
62945222	0	0	0	0	1	0	0
62945223	0	0	0	0	0	0	0
62945227	0	0	0	0	0	0	0
62945231	0	0	0	0	0	0	0
62945232	0	0	0	0	0	0	0

62945234	0	0	0	0	0	0	0
62945236	1	1	1	0	1	0	1
62945239	0	1	0	0	1	0	1
62945244	0	0	0	0	1	0	0
62945247	0	0	0	0	1	0	1
62945250	0	0	0	0	0	0	0
62947256	0	0	0	0	0	0	0
62947257	0	0	0	0	0	0	0
62947258	0	0	1	0	0	1	0
62947259	0	1	1	0	0	0	0
62947260	0	0	0	0	0	0	0
62947261	0	1	0	1	0	0	0
62947262	0	0	0	0	0	0	0
62947263	0	0	0	1	0	0	1
62947264	1	0	0	0	0	0	1
62947265	1	0	0	0	0	0	1
62947267	0	1	0	1	0	0	0
62947268	1	1	0	0	0	1	0
62947269	1	1	0	0	0	1	0
62947273	0	0	0	0	0	0	0
62947275	0	0	0	0	1	0	0
62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	0	0	0	0	0
62947281	0	0	0	0	0	0	0
62947283	0	0	0	0	0	0	0
62947285	0	0	0	0	0	0	0
62947286	0	0	0	0	0	0	0
62947287	0	1	0	0	0	0	1
62947289	0	0	1	0	0	1	0
62947290	0	0	0	0	0	0	0
62947292	1	0	0	0	1	0	1
62947293	0	0	0	0	0	0	0
62947297	0	0	0	0	0	0	0

Bird Id Number	5/11/2009	5/12/2009	5/13/2009	5/15/2009	5/17/2009	5/19/2009	5/20/2009
55961710	0	0	0	0	0	1	0
62922106	0	0	0	0	0	0	0
62922116	0	0	0	0	0	0	0
62922117	0	0	0	0	0	0	0
62922126	0	1	0	0	1	0	0
62922134	1	0	0	0	0	1	0
62922139	0	0	1	0	0	0	0
62922140	0	1	0	0	0	0	0
62922150	0	0	0	0	0	0	0
62922160	0	0	0	0	0	0	0
62922162	0	0	0	0	0	0	0
62922163	0	0	1	0	0	0	0
62922178	0	0	0	0	0	0	0
62922179	0	1	1	0	0	0	0
62922184	0	0	1	0	0	1	0
62923420	0	0	0	0	0	1	0
62923427	0	0	0	1	0	0	0
62923435	0	0	0	0	0	1	0
62923439	0	0	1	0	0	0	0
62923448	0	0	0	0	0	0	0
62923452	0	0	0	0	0	0	0
62923460	0	0	0	0	0	1	0
62923463	1	0	1	0	0	0	0
62923477	0	0	0	0	0	0	0
62923487	0	0	0	0	0	1	0
62923490	0	0	0	0	0	0	0
62923491	0	1	0	1	0	0	1
62923492	0	1	0	1	0	0	1
62938723	0	0	0	0	0	1	0
62938724	0	0	0	0	0	1	0
62945201	0	0	0	0	0	1	0
62945202	0	0	1	0	0	1	0
62945211	0	0	0	0	0	0	0
62945214	0	1	0	1	0	0	0
62945217	0	0	0	0	0	0	0
62945221	0	0	0	0	0	0	0
62945222	0	0	0	0	0	0	0
62945223	0	0	0	0	0	0	0
62945227	0	0	0	0	0	0	0
62945231	0	0	0	0	0	1	0
62945232	0	0	0	0	0	0	0

62945234	0	0	0	0	0	0	0
62945236	0	0	0	0	0	0	0
62945239	0	0	1	0	0	0	0
62945244	0	0	1	0	0	0	0
62945247	0	0	1	0	0	1	0
62945250	0	0	0	0	0	0	0
62947256	0	0	0	0	0	1	0
62947257	0	0	0	0	0	0	0
62947258	0	0	0	0	0	0	0
62947259	0	0	0	1	1	0	0
62947260	0	0	0	0	1	0	1
62947261	1	0	1	0	0	0	0
62947262	0	0	1	0	0	0	0
62947263	1	0	0	0	0	1	0
62947264	0	0	1	0	0	1	0
62947265	0	0	1	0	0	1	0
62947267	1	0	1	0	0	1	0
62947268	0	1	0	0	0	0	1
62947269	0	1	0	1	1	0	1
62947273	0	0	0	0	0	0	0
62947275	0	0	0	0	0	0	0
62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	1	0	0	0	0
62947281	0	0	0	0	0	0	0
62947283	0	0	1	0	0	0	0
62947285	0	0	0	0	0	0	0
62947286	1	0	1	0	0	0	0
62947287	0	0	1	0	0	0	0
62947289	0	1	0	0	1	0	0
62947290	0	0	0	0	0	0	0
62947292	0	0	1	0	0	1	0
62947293	0	0	0	0	0	1	0
62947297	1	0	1	0	0	1	0

Bird Id Number	5/22/2009	5/24/2009	5/25/2009	5/26/2009	5/27/2009	5/29/2009	5/30/2009
55961710	1	1	0	0	1	0	0
62922106	0	0	0	0	1	0	0
62922116	0	0	0	0	0	0	1
62922117	0	1	0	0	0	0	0
62922126	0	0	0	0	0	0	1
62922134	1	1	0	0	1	0	0
62922139	0	0	1	0	0	0	1
62922140	0	0	0	1	0	0	0
62922150	1	1	0	0	0	0	0
62922160	0	0	0	0	0	0	0
62922162	0	0	0	0	0	0	0
62922163	0	0	0	0	0	0	0
62922178	0	0	0	0	0	0	0
62922179	0	0	0	0	1	0	0
62922184	0	1	0	0	1	1	0
62923420	1	0	0	0	0	0	1
62923427	0	0	0	0	0	0	0
62923435	1	0	0	0	0	0	0
62923439	0	0	0	0	0	0	0
62923448	0	0	0	0	0	0	0
62923452	0	0	0	0	0	0	1
62923460	1	0	1	0	0	0	0
62923463	0	0	1	0	0	0	0
62923477	0	0	0	0	0	0	0
62923487	0	0	0	0	0	0	1
62923490	0	0	0	0	0	0	0
62923491	0	0	0	1	0	0	0
62923492	0	0	0	1	0	0	0
62938723	0	0	0	0	0	0	0
62938724	1	0	0	0	0	0	1
62945201	1	1	0	0	1	0	0
62945202	1	1	0	0	1	0	0
62945211	1	0	0	0	0	0	0
62945214	0	0	0	0	0	1	0
62945217	1	1	0	0	1	0	0
62945221	0	0	0	0	0	0	0
62945222	0	0	0	0	0	0	1
62945223	1	0	0	0	0	0	1
62945227	0	0	0	0	0	0	0
62945231	1	1	0	0	1	0	0
62945232	0	0	0	0	1	0	0

62945234	0	0	0	0	0	0	0
62945236	1	1	0	0	1	0	0
62945239	0	1	0	0	1	0	0
62945244	0	0	0	0	1	0	0
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62947283	1	1	0	0	0	0	0
62947285	0	0	0	0	0	0	0
62947286	1	0	0	0	0	0	0
62947287	0	0	0	0	0	0	0
62947289	0	0	0	1	1	0	1
62947290	0	0	0	0	0	0	0
62947292	0	1	0	0	1	0	0
62947293	0	0	0	0	0	0	0
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Bird Id Number	5/31/2009	6/1/2009	6/2/2009	6/3/2009	6/5/2009	6/7/2009	6/8/2009
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62922117	0	0	0	0	0	0	0
62922126	0	0	0	0	0	1	0
62922134	0	0	0	0	0	0	0
62922139	0	0	0	0	0	0	0
62922140	0	0	0	0	0	1	0
62922150	0	0	0	0	0	0	0
62922160	0	0	0	0	0	0	0
62922162	0	0	0	0	0	0	0
62922163	0	0	0	0	0	0	0
62922178	0	0	0	0	0	0	0
62922179	0	0	1	0	0	1	0
62922184	1	0	0	1	0	0	0
62923420	0	0	0	0	0	0	0
62923427	0	0	0	0	0	0	0
62923435	0	0	0	0	0	0	0
62923439	0	0	0	0	0	0	0
62923448	0	0	0	0	0	0	0
62923452	0	0	0	0	1	1	0
62923460	0	0	0	1	0	0	0
62923463	0	1	0	1	0	0	1
62923477	0	0	0	0	0	0	0
62923487	0	0	0	0	0	0	0
62923490	0	0	0	0	0	0	0
62923491	0	0	1	0	1	1	0
62923492	0	0	0	0	0	0	0
62938723	1	0	0	1	0	0	0
62938724	0	0	0	0	0	0	0
62945201	1	0	0	1	0	0	0
62945202	1	0	0	1	0	0	0
62945211	0	0	0	0	0	0	0
62945214	0	0	0	0	0	0	0
62945217	1	0	0	1	0	0	0
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62945231	0	0	0	0	0	0	0
62945232	0	0	0	1	0	0	0

62945234	0	0	0	0	0	0	0
62945236	1	0	0	1	0	0	0
62945239	1	0	0	1	0	0	0
62945244	0	0	0	0	0	0	0
62945247	1	0	0	1	0	0	0
62945250	0	0	0	0	0	0	0
62947256	0	0	0	1	0	0	1
62947257	0	0	0	0	1	1	0
62947258	0	0	0	0	1	1	0
62947259	0	0	1	0	1	1	0
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62947261	0	0	0	1	0	0	1
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62947263	0	1	0	1	0	1	1
62947264	0	0	0	1	0	0	0
62947265	1	0	0	0	0	0	0
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62947268	0	0	1	0	1	0	0
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62947275	0	0	0	0	0	0	0
62947276	0	0	0	0	0	0	0
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62947279	0	0	0	0	0	0	0
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62947283	0	0	0	0	0	0	0
62947285	0	0	1	0	0	0	0
62947286	0	0	0	0	0	0	0
62947287	0	0	0	0	0	0	0
62947289	0	0	1	0	0	1	0
62947290	0	0	0	0	0	0	0
62947292	1	0	0	1	0	0	0
62947293	0	0	0	0	0	0	0
62947297	0	1	0	1	0	0	1

Bird Id Number	6/9/2009	6/10/2009	6/12/2009	6/14/2009	6/15/2009	6/16/2009	Territorial
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62922116	0	0	0	0	0	0	1
62922117	0	0	0	0	0	0	1
62922126	0	1	0	0	0	0	1
62922134	0	0	0	0	1	0	1
62922139	0	0	0	0	0	0	1
62922140	0	0	0	0	0	0	1
62922150	1	0	0	0	0	0	1
62922160	0	0	0	0	0	0	1
62922162	0	0	0	0	0	0	1
62922163	0	0	0	0	0	0	1
62922178	0	0	0	0	0	0	1
62922179	1	0	0	0	0	0	1
62922184	1	0	1	0	0	0	1
62923420	0	0	0	0	0	1	1
62923427	0	0	0	0	0	0	1
62923435	0	0	0	0	0	0	1
62923439	0	0	0	0	0	0	0
62923448	0	0	0	0	0	0	1
62923452	0	0	0	0	0	0	0
62923460	0	0	0	0	0	1	1
62923463	0	1	0	0	0	1	1
62923477	0	0	0	0	0	0	1
62923487	0	0	0	0	0	0	0
62923490	0	0	0	0	0	0	0
62923491	1	0	0	1	0	0	1
62923492	1	0	0	0	0	0	1
62938723	0	0	1	0	0	0	1
62938724	0	0	0	0	0	0	1
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62945202	1	0	1	0	1	0	1
62945211	0	0	0	0	0	0	1
62945214	0	0	0	0	0	0	0
62945217	1	0	1	0	1	0	1
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62945222	0	0	0	0	0	0	0
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62945231	0	0	0	0	1	0	1
62945232	1	0	0	0	0	0	1

62945234	1	0	0	0	0	0	0
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62945247	1	0	1	0	1	0	0
62945250	1	0	0	0	0	0	1
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62947264	1	0	0	0	1	0	1
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62947273	0	0	0	1	0	0	0
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62947276	0	0	0	0	0	0	0
62947277	0	0	0	0	0	0	0
62947279	0	0	0	0	0	0	0
62947281	0	1	0	0	0	0	0
62947283	0	0	0	0	0	0	0
62947285	0	0	0	0	0	0	1
62947286	0	0	0	0	0	0	0
62947287	0	0	0	0	0	0	1
62947289	0	0	0	0	0	0	1
62947290	0	1	1	0	0	0	0
62947292	1	0	1	0	1	0	1
62947293	0	0	0	0	0	0	1
62947297	0	1	0	1	0	0	0

Bird Id Number	Non-territorial	Average Distance
55961710	0	118
62922106	0	104
62922116	0	260
62922117	0	124
62922126	0	151
62922134	0	281
62922139	0	136
62922140	0	231
62922150	0	336
62922160	0	46
62922162	0	118
62922163	0	151
62922178	0	13
62922179	0	94
62922184	0	80
62923420	0	203
62923427	0	121
62923435	0	227
62923439	1	284
62923448	0	108
62923452	1	179
62923460	0	153
62923463	0	240
62923477	0	115
62923487	1	198
62923490	1	99
62923491	0	214
62923492	0	262
62938723	0	179
62938724	0	182
62945201	0	140
62945202	0	148
62945211	0	82
62945214	1	155
62945217	0	130
62945221	1	281
62945222	1	147
62945223	1	181
62945227	1	191
62945231	0	301
62945232	0	78

62945234	1	568
62945236	0	133
62945239	0	143
62945244	1	98
62945247	1	145
62945250	0	261
62947256	0	229
62947257	0	228
62947258	0	213
62947259	1	127
62947260	0	75
62947261	0	90
62947262	0	76
62947263	0	153
62947264	0	62
62947265	0	64
62947267	0	230
62947268	0	126
62947269	0	117
62947273	1	236
62947275	1	352
62947276	1	210
62947277	1	101
62947279	1	304
62947281	1	281
62947283	1	116
62947285	0	127
62947286	1	330
62947287	0	189
62947289	0	146
62947290	1	397
62947292	0	143
62947293	0	80
62947297	1	239

CHAPTER 2:

DIFFERENCES IN NESTING BEHAVIOR BETWEEN CAPTIVE RAISED WHOOPING CRANES AND WILD SANDHILL CRANES

INTRODUCTION

In 1941, only 15 whooping cranes (*Grus americana*) remained in one wild population wintering at Aransas National Wildlife Refuge, Aransas, Texas (Allen 1952). The creation of national parks, wildlife refuges, the Migratory Bird Act, and hunting restrictions allowed the only surviving wild population of whooping cranes to grow to 257 (95% CI 178-362) in 2012 (Harrell and Bidwell 2013). Despite population growth, the whooping crane is still the most highly endangered crane species in the world (Archibald and Lewis 1996). In addition, the whooping crane is confined to two areas (breeding grounds and wintering grounds) for most of the year, heightening the risk of one random, catastrophic event leading to extinction (United States Fish and Wildlife Service [USFWS] 1994; Urbanek et al. 2010b). Currently, whooping cranes overwinter in Aransas, Texas and breed in Wood Buffalo Park, Canada (Johns 2008). The wild population of whooping cranes is experiencing exponential growth rates, with annual survival rates of 0.87 – 1.0 for ages 1-26. These birds also are reproducing successfully, with 57-61% of adult females fledging young (1977-1988) (Gil-Weir et al. 2012). In 1994, the Whooping Crane Recovery Team recommended the establishment of two wild populations of whooping cranes in addition to the existing population, in hopes of increasing the overall population and possibly removing them from the endangered species list (USFWS 1994).

Reintroduction of extirpated species to previously occupied habitat is often required to conserve imperiled species (Kleiman 1989). A reintroduction may release wild or captively-raised individuals into previously occupied habitat. Founders for the whooping crane reintroduction could not be taken from the wild population because of the small population size. Instead, a captive flock of whooping cranes was initiated at the Patuxent Wildlife Research Center in 1967 with eggs taken from whooping crane nests in Wood Buffalo, Canada (Ellis and Gee 2001). Whooping cranes lay one to two eggs, but usually only raise one colt, thus it was believed no significant harm was done to the population (Ellis and Gee 2001). The reintroduction of a non-migratory population began in Florida in 1992 (Spalding et al. 2009). A second reintroduction attempt began in 2001 with the eastern migratory population (EMP) of whooping cranes, which breed in Wisconsin and spend the winter in Florida (Whooping Crane Eastern Partnership [WCEP] 2012; U.S. Dept. of the Interior 2001). Founders for the EMP of whooping cranes were taken from the captive population at Patuxent Wildlife Research Center and the International Crane Foundation (U.S. Department of the Interior 2001). Whooping cranes for the EMP were costume raised and taught to follow an ultra-light aircraft for migration from Wisconsin to wintering grounds in Florida (WCEP 2012). However, after thirteen years of reintroduction, the EMP is not yet self-sustaining primarily because of nest failures on breeding grounds at Necedah National Wildlife Refuge (Urbanek et al. 2010a; WCEP 2012). Nest failures are attributed to abandonment by adult cranes, but the cause of abandonment is still debated (Urbanek 2010a; King et al. 2013a). Competing hypotheses for low EMP whooping crane nest success are: 1) captive birds do not exhibit appropriate nesting behaviors due to captive breeding, 2) black fly infestations cause nest abandonment, and 3) the birds are young and will become good breeders in time (Urbanek 2010b). Additionally, nest predation may influence success for reintroduced cranes (Butler 2009).

We attempted to observe nesting behavior of wild and captive raised cranes concurrently in order to test the hypothesis that captive raised cranes exhibit inappropriate nesting behaviors. We suggest that comparing sandhill crane nesting behavior to whooping crane behavior may elucidate differences between the species and consequently the reason for whooping crane nest abandonment. Whooping crane behavior in the EMP may be affected by captive rearing, that causes improper behavioral development. Whooping crane behavior is both innate and learned and captively-raised individuals may not exhibit the proper behavioral adaptations to survive and reproduce (Snyder et al. 1996). In 1975, an attempt to cross-foster whooping cranes with wild sandhill crane (*Grus canadensis*) adults in Grey's Lake, Idaho failed to produce pair bonds between cross-fostered whooping cranes, assumably because of imprinting of the young whooping cranes on sandhill crane adults (Drewien and Bizeau 1977; USFWS 1994). Imprinting refers to the rapid learning of characteristics encountered during an early developmental stage (Wallace 1973). As a result, whooping cranes of the EMP were puppet reared to reduce human contact, and avoid improper imprinting (USFWS 1994). In contrast to imprinting, whooping cranes in the EMP learn to migrate by following ultra-light aircraft (USFWS 1994). Learned and innate behaviors of whooping cranes may be influenced by captive breeding and could influence nest success and survival. King et al. (2013b) found some evidence to support the hypothesis that a crane's lineage, meaning the number of generations of captive breeding, may negatively affect its breeding success.

Reintroduced populations may experience persistent fitness problems from inbreeding and loss of genetic diversity because of a small founder population (Jamieson 2010), and genetic differences may be manifested in abnormal behaviors. Genetic analysis of the mitochondrial DNA control region of whooping crane museum specimens revealed significant differences in haplotype number and frequency in pre-bottleneck individuals when compared to the extant population (Glenn et al. 1999). Inbreeding is unavoidable because of the small number of cranes in the captive population. Whooping cranes from the EMP have been observed displaying appropriate mating behavior (such as copulation) and nest initiation behavior, yet copulation and nesting were not taught to captive individuals. These behaviors are likely innate. Despite exhibiting appropriate nesting and copulation behaviors, captively-raised cranes may be lacking the correct behavioral traits to successfully incubate a nest to hatching.

Nest success is commonly influenced by predators, and marsh nesting species are more susceptible to predation than arboreal nesters (Ricklefs 1969). Recruitment by greater sandhill cranes in Oregon increased during 12 years of predator removal, indicating predation by coyotes (*Canis latrans*) limited recruitment (Littlefield 2003). Survival of the captively-raised and reintroduced population of whooping cranes in Florida has been negatively affected by bobcat (*Lynx rufus*) predation (Kreger et al. 2006). Captively-raised animals may lack appropriate fear responses to predators, thus requiring instruction before release (Heezik et al. 1999). Costume rearing was shown to increase pre-release vigilance in common ravens (*Corvus corax*) (Valutis and Marzluff

1999). Survival one year after release was significantly higher in Houbara bustards (*Chlamydotis macqeenii*) who were taught to fear predators with a live, tame fox compared to those trained with a model fox (Heezik 1999).

In addition to regular nesting behaviors, EMP whooping cranes may lack adaptive behaviors for coping with ectoparasites specific to the breeding grounds in Wisconsin. Ectoparasites cause avian hosts to be inattentive to the nest (Bukaciński and Bukacińska 2000), and captively-raised cranes may differ from wild cranes in their behavioral response to ectoparasites. Urbanek et al. (2010b) first hypothesized that black flies (Simuliidae spp.) affect nesting whooping cranes after observing a whooping crane pair leave their nest while visibly irritated by black flies. Black flies are not naturally found in the breeding area of the wild whooping crane population (Adler et al. 2004), and thus whooping cranes may not have evolved the best avoidance behaviors for these parasites. King et al. (2013b) identified a strong negative relationship between ornithophilic black fly abundance and daily nest survival rate of whooping crane nests on NNWR, and Converse et al. (2013) also found that black flies (*Simulium annulus*) may be negatively affecting whooping crane reproduction.

Avian species use several methods to combat ectoparasites, such as preening, bathing, and dusting (Clayton et al. 2010). Incubating birds cannot escape from ectoparasites as easily as non-incubating birds, and thus may abandon nests. Ectoparasites were indicated in the abandonment of nests by great tits (*Parus major)* as well (Oppliger et al. 1994). Common gulls (*Larus canus*) in Poland spent more time off territory and wheeling above nests on years with massive black fly outbreaks than years without (Bukaciński and Bukacińska 2000). Whooping cranes have been observed using bill flicks, head shakes, or head rubs to disperse black flies, and these behaviors have been used as indicators of black fly harassment (Urbanek 2010b; WCEP 2012).

Greater sandhill cranes (*G. c. tabida)* also breed in NNWR, and share several natural history characteristics with whooping cranes (Johnsgard 1983). Both species of crane are monogamous, share incubation between genders, build platform nests in or near wetland areas, and lay one or two eggs in nests (Walkinshaw 1973; Archibald and Lewis 1996). Sandhill cranes were sufficiently similar to whooping cranes in nesting and parental care to be surrogates to whooping cranes in previous studies (Drewien and Bizeau 1977). Similar to whooping cranes, greater sandhill cranes went through a population bottleneck in the early 20th century, but greater sandhill crane populations have recovered to an estimated cross-country population of 65,000-75,000 cranes in 1995 (Henika 1936; Meine and Archibald 1996). Greater sandhill cranes nesting in NNWR are currently reproducing at a sustainable rate (King et al. 2013b, NNWR unpb. data).

Our first objective was to identify behaviors that differ between successful and unsuccessful crane nests of both species to better understand why population growth is limited in the endangered whooping crane. Our second objective was to determine if whooping cranes and sandhill cranes differed in incubation behaviors. We hypothesized that captively-raised whooping cranes in the EMP would be behaviorally different than wild cranes, rendering them ill-prepared to incubate eggs, and resulting in low nesting success (Kreger et al. 2006; King et al. 2013b). We hypothesized that cranes with successful nests would have higher nest attendance than cranes that incubate unsuccessful nests. In order to test these hypotheses, we monitored wild sandhill cranes and captively-raised wild whooping cranes at Necedah National Wildlife Refuge concurrently in order to compare and contrast incubation behaviors.

METHODS

Study Area

Necedah National Wildlife Refuge encompasses 298,240 ha of land in Juneau County, Wisconsin (King et al. 2013b). The habitat is characterized by marsh-land and pools, grasslands, and woodlands (Urbanek et al. 2005; King et al. 2013b). Sedges (*Carex* spp.), cat-tails (*Typha spp.*), reed canary grass (*Phalaris arundinacea*), and bulrushes (*Scirpus* spp.) constitute most of the vegetation in wetland areas (Urbanek et al. 2005; King et al. 2013b). Wooded areas contain species such as black oak (*Quercus velutina*), northern pin oak (*Q. ellipsoidalis*), jack pine (*Pinus banksiana*), and aspen (*Populus grandidentata* and *P. tremuloides*) (King et al. 2013b). The refuge is actively managed through prescribed fire, mowing, and drawing down of pools in order to maintain suitable habitat for Karner blue butterflies (*Lycaeides melissa samuelis*), whooping cranes, and bald eagles (*Haliaeetus leucocephalus*), all federally listed species (US Department of the Interior 2002). Necedah National Wildlife Refuge also contains the eastern timber wolf (*Canis lupus*), a recently delisted species (US Department of the Interior 2002). Black bears (*Ursus americanus*), white-tailed deer (*Odocoileus virginianus*), red foxes (*Vulpes vulpes*), raccoons (*Procyon lotor*), coyotes (*Canis latrans*), and muskrats (*Ondatra zibethicus*) are also found on the refuge (USFWS 2004). Many migratory bird species use the refuge as a stop-over during migration (US Department of the Interior 2002).

The climate in central Wisconsin consists of short summers and long, cold winters. High temperatures in Necedah average 21°C in July (data 1971-2000). Low temperatures in January average -9.5°C (data 1971-2000) (Wisconsin State Climatology Office 2007). Average precipitation is highest in August at 11.43 cm and lowest in February at 2.54cm (data 1971-2000) (Wisconsin State Climatology Office 2007.

Nest Searches and Monitoring

All whooping cranes in this population are identified by a unique color band combination on the leg, and some are fitted with radio-telemetry transmitters. Sandhill cranes are unmarked. The entire refuge was surveyed daily by vehicle to determine which crane pairs had returned from migration. Upon return, whooping cranes were monitored daily or every other day to assess nesting status.

Observations were made from March – June 2014 by technicians and biologists at Necedah National Wildlife Refuge, Necedah, WI. We sighted cranes with spotting scopes from vehicles on refuge roads or from trails on foot. When a crane was observed, we recorded the number of cranes, location, and status (paired or single). Two birds < 5m apart were considered paired with the potential to have a nest (Austin et al. 2007). Paired birds were observed every day or every 2 days for nesting behaviors such as unison calling, nest building, or foraging alone (Johnsgard 1983; Urbanek et al. 2010a). Most whooping and sandhill crane nests were located using aircraft and approximate UTM coordinates were recorded. We waited at least 5 days after nest initiation to visit whooping crane nests in order to decrease the probability of abandonment. The exact day of initiation was not available for sandhill crane nests because sandhill cranes are not marked thus individuals could not be monitored daily. Sandhill cranes also are much more difficult to observe because of plumage camouflage. Sandhill crane nests were visited as soon as possible after initiation to deploy a camera and float eggs to determine nest initiation date (Fisher and Swengel 1991). Sandhill crane eggs were floated in warm water at the nest and a picture was taken of the angle and position of the egg in the water column. A diagram of sandhill crane egg floating positions and egg age was compared to each picture to calculate initiation date (Fisher and Swengel 1991).

The first whooping crane nest was initiated on April 8, 2014, and the first sandhill crane nest was initiated on April 7, 2014. On the first visit to a crane nest, we deployed a trail camera (Reconyx ™, HyperFire HC600, Reconyx Inc., Holmen, WI or Bushnell® Trophy Cam ™, Bushnell Outdoor Products, Overland Park, KS) approximately three meters from each nest. We attempted to place cameras at equal distances from each nest while accounting for landscape differences. We oriented cameras away from direct sunlight in order to minimize glare. We programmed each camera to take one photo every five minutes for 24 hours each day. Cameras were left at nest sights until the nest was either abandoned or successful. Successful nests were defined as those hatching at least one egg (Silvy 2012). Whooping cranes and sandhill cranes incubate for an average of 29 and 28-31 days, respectively (Walkinshaw 1973; Johnsgard 1983). We evaluated nests that could be viewed without disturbance to the birds every day to determine status. Pairs were observed for signs of nest failure, such as both members of a pair seen off the nest (Johnsgard 1983; Urbanek 2010b). We visited nests suspected of failure as soon as possible in order to ascertain the reason for failure.

Incubation Behavior

We copied pictures from the SD memory card of each trail camera to an external hard drive. Original pictures were stored in one folder, and copies of the originals were used for analysis. The free downloadable program ReNamer (ver 5.74.12) was used to rename picture files with nest identifier, date, and time the picture was taken (Harris et al. 2010). We used another free downloadable program ExifTool (ver 9.60) to extract meta-data in a tab delineated format from Reconyx and Bushnell cameras (Sundaresan et al. 2011). After renaming and extracting meta-data information, we tagged each picture using the free Google picture organizer Picasa (Sundaresan et al. 2011).This program allows the user to attach “tags” or phrases to each photo file as meta-data. Tags are created by the user and stored for quick access. The first four pictures after the crane returned to the nest were disregarded to decrease the effect of camera placement on behavior. The number and species of adult cranes, colts, and other animals were recorded for each picture. The location of each bird was noted (on platform or in water) as well as its behavior. Each crane could be assigned three behavior tags which increased in level of detail. The first behavior tag could be one of five options: incubation, brooding, flying, standing, or away from nest if no crane was visible. Although our cameras were pointed at the nest, we occasionally saw a crane in the process of landing which we tagged as “flying.” Second, we noted whether the crane’s head was up or tucked in a sleeping position. Third, if the head was up, one of nine behaviors was assigned: bill flick, head rub, preening, calling, manipulating platform, unison call, calling, alert, and other (Tacha 1987). If the crane was standing in the water, the photo was tagged as walking or foraging. If the position of the crane or the lighting of the photo did not allow us to discern past the first or second tier of specificity, we left the third tier behavior column blank. For example, in some pictures we could see that a crane was incubating the nest, and its head was up, but the head was facing away from the camera and we could not tag the photo with the final tier of behaviors (preening, calling, etc.). If necessary, the pictures immediately before and after the picture in question were used for context in order to decide among behavior categories. Percent time spent in vigilant behavior was calculated by combining time spent incubating, standing in the water, or standing on nest with head up. Photos in which the crane was preening, foraging, manipulating eggs, or manipulating the nest were considered non-vigilant behavior. For pictures from whooping crane nests, band combinations and crane ID numbers were recorded when possible. We initially attempted to identify incubation swaps, but the five minute interval between pictures was too long for us to be confident that we were not missing swaps. Two observers participated in reviewing pictures and identifying behaviors. Before commencement of data analysis, both observers tagged the same 850 pictures and compared tags in order to ensure agreement on the majority of behaviors. Definitions and examples of each behavioral category can be found in Appendix A.

After all pictures had been tagged, we used ExifTool to extract behavior tags from the meta-data of each picture into a tab delineated file. This file was imported into Excel using the text import wizard. In this way, we were able to determine the percent of time spent each day on each behavior of interest: bill flicks, head rubs, preening, calling, manipulating platform, unison calls, and alert behavior. The percent time spent in any behavior was calculated by dividing the number of pictures documenting the behavior by the total number of pictures under observation (McGowan and Simons 2006). We used only photos from a half hour before sunrise to a half hour after sunset in analysis. Although the cameras took pictures twenty four hours a day, due to the distance of some cameras from nests we were unable to categorize behaviors at night.

Statistical Analysis

Initially, Julian date and day since nest initiation were regressed against behavior frequency to determine if there were any systematic trends in behaviors over time. Burnam (2008) found that stage of incubation and time of season influenced nest attendance by northern bobwhites (*Colinus virginianus*). Because we did not identify an effect of Julian date or day since start of incubation on behavior (Tables 2.1 & 2.2) we used a two way factorial ANOVA with sub-sampling for each behavior to analyze behavioral differences by species and fate of nest (successful or unsuccessful) (Kutner et al. 2004). We considered our experimental unit to be the nest and days to be subunits. Sub-sampling resulted from multiple daily observations of whooping crane behavior on nests, and was accounted for by nesting repeated observations within each factorial combination (Kutner et al. 2004). We used the mean squared error for nests as the error term in the ANOVA, and type III sum of squares (Kutner et al. 2004). We considered $\alpha \leq 0.05$ as significant. We did transform the data using the arcsin transformation. However, the results were similar and the behaviors which were significantly different between groups did not change.

RESULTS

We monitored nine whooping crane nests and eleven sandhill crane nests at Necedah National Wildlife Refuge during the 2014 breeding season. Four sandhill crane nests were omitted from analysis. Two were omitted because of human induced nest failure, one because of uncertainty in initiation date, and one because the colt had already hatched when the camera was deployed. This left a total of nine whooping crane nests and seven sandhill crane nests for analysis. Five whooping crane and four sandhill crane nests were successful. Apparent nest success for monitored nests was 0.56 for whooping cranes and 0.57 for sandhill cranes. Of the three unsuccessful sandhill crane nests, one nest was abandoned, one nest was destroyed by predators, and one failed due to abandonment after an adult crane appeared to roll one egg out of the nest. All four unsuccessful whooping crane nests were abandoned.

We reviewed 16,487 sandhill crane pictures and 25,544 whooping crane pictures for a total of 42,031 pictures. Pictures per nest varied because cameras were deployed when nests were at different stages of incubation, and because of technical difficulties. The average number of sandhill crane pictures per nest was 2355.29 (SD = 1871.29), and the average number of whooping crane pictures per nest was 2838.22 (SD = 1112.84) (Table 2.3). Pictures at sandhill crane nests were taken over an average of 18 days (SD = 6.8) and whooping crane pictures were taken over an average of 16 days (SD=6.8).

No systematic trend in any behavior by date or day from start of incubation was found in linear regression analyses. Regressions with a significant p-value had very small R^2 values (max $R^2 = 0.111$), and negligible slopes (Tables 2.1 and 2.2). For whooping cranes, we found a significant relationship between percent time preening and day from start of incubation. We also identified relationships between Julian date and percent time incubating, head rubs and time away from nest. However, slopes of lines were near 0.00, indicating slight relationships. For sandhill cranes, we identified a significant relationship between percent time spent incubating with head down and day from start of incubation. Additionally, we found relationships between incubation with head down and time away from nest by Julian date. Again, slopes of lines were near 0.00 indicating slight relationships with little biological significance (Kutner et al. 2004).

We found a significant difference in percent time spent incubating by fate of nest ($F_{(0.5),1,12}$ =14.24, P = 0.0027) (Table 2.4). Cranes (both species) incubated more often at successful nests, 96.0% (CI = 94.4% - 97.5%), than unsuccessful nests, 87.3% (CI = 84.9% - 97.5%) (Table 2.5). We also found a significant difference in percent time spent away from the nest by species ($F_{(0.5),1,12}$ =5.33, P = 0.0395) and by fate ($F_{(0.5),1,12}$ =11.7, P = 0.0051) (Table 2.4). Whooping cranes spent more time away from the nest than sandhill cranes and nests that were successful had adult cranes at the nest more often than unsuccessful nests (Tables 2.5 & 2.6). Whooping cranes spent a higher percentage of the day away from the nest, 6.6% (CI = 4.7% - 8.6%), than sandhill cranes, 1.5% (CI = 0.0% - 8.6%), and both crane species were away from unsuccessful nests more often than successful nests, 7.85% (CI = 5.5% - 10.0%) and 0.3% (CI = 0.0% - 1.8%) respectively. (Tables 2.5 & 2.6). The interaction of species and fate was almost significant with a P-value of 0.0527 ($F_{(0.5),1,12}$ = 4.62) (Table 2.4). Cranes form successful nests spent less time manipulating eggs than unsuccessful nests ($F_{(0.5),1,12}$ = 16.97, P = 0.0014)(Table 2.4). All other behaviors were similar between successful and unsuccessful nests and between whooping cranes and sandhill cranes (Tables 2.5,2.6, & 2.7).

DISCUSSION

We tested the hypothesis that successful crane nests would exhibit higher nest attendance than unsuccessful crane nests of both species. Whooping and sandhill cranes that hatched eggs spent an average of 96.0% (CI = 94.4% - 97.5%) of their time incubating per day (Table 2.6). Adults of both species from unsuccessful nests spent only an average of 87.3% (CI = 84.9% - 97.5%) of their time per day incubating (Table 2.6). Cranes with successful nests spent on average less time manipulating eggs per day, 1.6%

(CI = 1.4% - 1.9%), than cranes with unsuccessful nests, 2.8% (CI = 2.4% - 3.3%) (Table 2.5). Additionally, cranes with successful nests spent significantly less time away from the nest on average, than cranes with unsuccessful nests, 0.3%(CI = 0.0% - 1.8%) and 7.8% (CI = 5.5% - 10.0%) respectively. These results are not surprising as low nest attendance has been associated with failed nests in both Puerto Rican parrots (*Amazon vittata*) (Wilson et al. 1997), and herring gulls (*Larus argentatus)* (Fox et al. 1978). Eggs must be kept at an almost constant temperature and humidity for optimal embryo development (Gabel and Mahan 1996). Unattended nests risk predation, stalled embryonic development, or embryo death due to temperature and humidity fluctuations (Gabel and Mahan 1996). Additionally, cranes must rotate eggs multiple times a day to avoid attachment of the embryo to the shell and mal-positioning of the embryo or air sac (Gabel and Mahan 1996). Cranes present at their nests for a higher percentage of time will be able to execute these tasks.

Our observations of whooping crane nest attentiveness are consistent with the results of King et al. (2013a) who used continuous video to monitor whooping crane nests from 2009 to 2011, and found that unsuccessful whooping cranes left nests unattended for a larger percentage of time per day than successful whooping cranes (n=20). King et al. (2013a) found that unsuccessful whooping crane pairs were absent from the nest an average of 4.5% (± 0.8, range 0.0 – 61.8%) of each day, and successful whooping crane pairs were away from the nest 1.2% (± 0.4, range 0.0 to 70.6%) of the day. Our results showed that percent time spent away from nest for unsuccessful whooping crane pairs and successful whooping crane pairs was 12% (CI = 9.4% - 16.1%

and 0.56% (CI = 0.0% - 2.5%) respectively (Table 2.7). Both studies lend credibility to a relationship between being at the nest and nest success.

It is not known if low nest attendance causes whooping crane nests to fail or if the embryos have already died and subsequently whooping cranes display low nest attendance. In 2011, three of seventeen abandoned whooping crane eggs contained dead embryos and two were infertile (King et al. 2013a). The developing colt is capable of movement and vocalization one to two days before hatching (Gabel and Mahan 1996). Through these signals, adult cranes may be able to discern the viability of eggs before the completion of incubation causing them to abandon an unsuccessful nesting attempt. However, EMP whooping cranes have incubated dummy eggs, which produce no signals of a live embryo (King et al. 2013a). One pair of whooping cranes incubated a dummy egg 17 days past full term (30 days) (King et al. 2013a).

Harassment by black flies has been hypothesized as a cause of nest abandonment in EMP whooping cranes (Urbanek et al. 2010a). Comfort behaviors such as head rubs and bill flicks could be reactions to harassment by black flies (WCEP 2012). Avian nest success and nest attendance can be reduced by the presence of ectoparasites, such as black flies (Bukaciński and Bukacińska 2000; King et al. 2013a). If black flies or another ectoparasite were the cause of nest abandonment, we would predict an increase in preening, bill flicks, and head rubs between successful and unsuccessful nests. Our results showed that successful and unsuccessful nests did not differ significantly in percent time spent preening, head rubbing, or bill flicking. It is interesting to note that we did not see any bill flicks from sandhill cranes. However, an abnormally low number of black flies were present during the 2014 breeding season compared to previous years

(Brad Strobel, unpublished data). In addition, black flies were not observed on the landscape until May 4 and did not reach peak numbers until May 20-28 (Brad Strobel, unpublished data). A very harsh winter before the 2014 breeding season may have caused the low number and late appearance of black flies.

We hypothesized that whooping cranes and sandhill cranes at Necedah National Wildlife Refuge may differ in incubation behaviors due to captive breeding. Captive breeding has been shown to reduce reproductive success in other species. After only one generation of captive breeding, reintroduced steelhead trout (*Oncorhynchus mykiss*) showed a decrease in reproductive success (Araki et al. 2007; Christie et al. 2012). Captive breeding may lower fitness in both the reintroduced individuals, and their wild born offspring (Araki et al. 2009). Kreger et al. (2006) found that certain behaviors were associated with whooping crane survival in a reintroduced population in Florida, but survival did not differ among birds reared under three captive-rearing methods. Ideally, in order to test the hypothesis that whooping crane reproductive success is influenced by captive breeding, behaviors of captively-raised EMP whooping cranes would be compared to behaviors of wild whooping cranes. For our research, wild whooping cranes were not available, so wild sandhill cranes were compared to captively-raised whooping cranes. We predicted that if captive rearing techniques were affecting whooping crane nesting behavior, we would identify behavioral differences between these species. Whooping cranes spent a higher percentage of time away from their nest per day than sandhill cranes. Interestingly, unsuccessful whooping cranes spent the most time away from their nest, 12.7%(CI = 9.4% - 16.0%). In comparison, unsuccessful sandhill cranes spent only 2.8% (CI = 0.0% - 5.9%) of their time away from the nest. These results could be due to the effects of captivity on whooping crane behavior, or species differences. More research is needed due to our small sample size.

Whooping cranes, a long-lived species, may abandon a current nesting attempt in favor of self-preservation and the potential to breed in the future. According to life history theory, evolution favors individuals who optimize the tradeoff between present and future reproduction (Sargent and Gross 1985; Cartar and Montgomerie 1987; Winkler 1987; Jones et al. 2002; Tulp and Schekkerman 2006). Incubation and foraging are mutually exclusive behaviors and this creates a conflict between self-preservation and reproductive success (Sargent and Gross 1985). Weather, ambient temperature, stress, loss of a mate, toxic chemicals, and low nutrient reserves have all been shown to affect incubation behavior, but relationships vary depending on species and environment (Fox et al. 1978; Cartar and Montgomerie 1987; Yorio and Boersma 1994; Mallory and Weatherhead 1993; Conway and Martin 2000; Thierry et al. 2013). Theoretically, long-lived birds should be more likely to abandon nests than short-lived birds because long-lived birds will have more chances to breed in the future (Spée et al. 2010). Wild whooping cranes have been observed to live thirty years, while captive cranes may live longer (Gil-Weir et al. 2012). Furthermore, bi-parental species should be less affected by stressors because shared incubation provides relief from stressors while not jeopardizing the nest (Tulp and Schekkerman 2006). We found that although both sexes incubate, the nest is not attended 100% of the time. If EMP whooping cranes are choosing to forego reproduction in order to invest more in subsequent years, we would predict that reproductive success would increase over time. However, reproductive success has remained very low in the Necedah population over the first 12 years of the reintroduction.

The U.S. Fish and Wildlife Service and collaborators are currently using reintroduction techniques in an effort to establish a self-sustaining population of whooping cranes in central Wisconsin. Although the wild population of whooping cranes, which supplied the founding eggs for the Wisconsin population, is reproducing successfully, the reintroduced whooping cranes at Necedah National Wildlife Refuge have had very little nest success over the past 13 years. Our research suggests that whooping cranes and sandhill cranes may be reproducing at similar rates at Necedah National Wildlife Refuge, but may exhibit different nesting behaviors. Conclusions from our data are speculative because of our small sample size; but, we believe that continued research into whooping crane nesting behavior in comparison to sandhill nesting behavior will provide insights into the causes of nest failures in EMP whooping cranes.

Specific information about incubation and parental care may aid in management decisions which will allow whooping crane colts to survive through the first year, when they are most vulnerable. The EMP had an apparent nest success rate of 0.20 (95% CI = 0.13- 0.28) from 2009-2011 (WCEP 2012). In order to reach the goal of a self-sustaining population, behaviors that contribute to survival of eggs through incubation must be identified.

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Table 2.1. Results of linear regression analyses of whooping crane behaviors and date from start of incubation and Julian dates.

	Whooping Crane							
	Incubation Date				Julian Date			
	P	R^2	Slope		P	R^2	Slope	
Incubation	0.77971	0.00053	0.00045	(-0.0027 - 0.0036)	0.00003	0.11148	-0.00566	(-0.0083 - -0.0031)
Head up	0.76844	0.00059	-0.00071	(-0.0055 - 0.0040)	0.08393	0.02018	0.00362	(-0.0005 - 0.0077)
Head down	0.74788	0.00070	0.00077	(-0.0040 - 0.0055)	0.09098	0.01931	-0.00354	(-0.0076 - 0.0006)
Vigilance	0.25572	0.00878	-0.00256	(-0.0070 - 0.0019)	0.86844	0.00019	0.00033	(-0.0036 - 0.0042)
Preen	0.00092	0.07217	0.00267	(0.0011 - 0.0042)	0.27230	0.00819	0.00079	(-0.0006 - 0.0022)
Away from nest	0.63354	0.00155	-0.00074	(-0.0038 - 0.0023)	0.00112	0.06989	0.00437	(0.0018 - 0.0070)

Table 2.2. Results of linear regression analyses of sandhill crane behaviors and date from start of incubation and Julian date.

	Sandhill Crane					
	Incubation Date			Julian Date		
	P	R^2	Slope	P	R^2	Slope
Incubation	0.14900	0.01672	-0.00147 (-0.0035 - 0.0005)	0.05768	0.02875	-0.00211 (-0.00429 - 0.0006)
Head up	0.06719	0.02676	0.00319 (-0.0002 - 0.0066)	0.05407	0.02960	0.00366 (-0.0006 - 0.0074)
Head down	0.02963	0.03758	-0.00369 (-0.0070 - -0.0004)	0.02343	0.04074	-0.00420 (-0.0078 - -0.0006)
Vigilance	0.21897	0.01216	0.00250 (-0.0015 - 0.0065)	0.40481	0.00560	0.00185 (-0.0025 - 0.0062)
Preen	0.42617	0.00511	0.00095 (-0.0014 - 0.0033)	0.17670	0.01467	0.00176 (-0.0008 - 0.0043)
Away from nest	0.08565	0.02364	0.00145 (-0.0002 - 0.0031)	0.03462	0.03550	0.00195 (0.0001 - 0.0003)

Table 2.3. Number of pictures reviewed and dates of data collection for sandhill and whooping crane nests at Necedah National Wildlife Refuge 2014.

Nest ID	Species	Pictures	Camera start date	Camera end date	Total days
1203.1	whcr[a]	3487	5/6/2014	5/25/2014	19
1303.1	whcr	2137	4/25/2014	5/7/2014	12
1509.1	whcr	3634	4/25/2014	5/15/2014	20
1607.1	whcr	2548	5/6/2014	5/20/2014	14
1707.1	whcr	427	4/30/2014	5/2/2014	2
2408.1	whcr	3844	4/25/2014	5/16/2014	21
2607.1	whcr	2574	5/2/2014	5/16/2014	14
3409.1	whcr	2880	5/7/2014	5/23/2014	16
w106.1	whcr	4013	4/25/2014	5/21/2014	26
SH02	sacr[b]	3461	5/1/2014	5/20/2014	19
SH04	sacr	5036	4/25/2014	5/22/2014	27
SH08	sacr	300	5/8/2014	5/26/2014	18
SH10	sacr	2684	4/30/2014	5/14/2014	14
SH12	sacr	1002	4/30/2014	5/6/2014	6
SH16	sacr	3761	4/30/2014	5/24/2014	24
SH17	sacr	243	5/5/2014	5/23/2014	18

[a] Whooping Crane

[b] Sandhill Crane

Table 2.4. Two-way factorial ANOVA evaluating whooping crane behaviors by species (sandhill crane or whooping crane), fate of nest (successful or unsuccessful), and the interaction of species and fate.

Behavior	Source	DF	F value	P value
Incubation	Species	1,12	3.92	0.0712
	Fate	1,12	14.24	0.0027 *
	Species*Fate	1,12	3.77	0.076
Incubation head up	Species	1,12	0.67	0.4293
	Fate	1,12	0.06	0.8102
	Species*Fate	1,12	0.17	0.6898
Incubation head tucked	Species	1,12	0.59	0.458
	Fate	1,12	0.07	0.803
	Species*Fate	1,12	0.19	0.6696
Vigilance	Species	1,12	1.82	0.202
	Fate	1,12	1.05	0.3256
	Species*Fate	1,12	0	0.9988
Preening	Species	1,12	2.09	0.1739
	Fate	1,12	0.05	0.8206
	Species*Fate	1,12	0.07	0.7956
Head rub	Species	1,12	1.38	0.2623
	Fate	1,12	0.25	0.6252
	Species*Fate	1,12	1.25	0.2857
Bill Flick	Species	1,12	2.14	0.1696
	Fate	1,12	0.88	0.3674
	Species*Fate	1,12	0.83	0.3789
Away from nest	Species	1,12	5.33	0.0395*
	Fate	1,12	11.7	0.0051*
	Species*Fate	1,12	4.62	0.0527
Manipulating egg	Species	1,12	0.88	0.3670
	Fate	1,12	16.97	0.0014*
	Species*Fate	1,12	0.59	0.4573

*Indicates statistical significance

Table 2.5 Least square mean and 95% confidence interval of percent time spent in each behavior by cranes with successful nests and cranes with unsuccessful nests.

	Unsuccessful		**Successful**	
Incubation	0.8729	(0.8489 - 0.9751)	0.9597	(0.9442 - 0.9751)
Head up	0.7436	(0.7106 - 0.7766)	0.7620	(0.7407 - 0.7833)
Head tucked	0.2533	(0.2205 - 0.2860)	0.2343	(0.2132 - 0.2554)
Vigilance	0.5076	(0.4736 - 0.5416)	0.5815	(0.5596 - 0.6034)
Preening	0.1247	(0.1085 - 0.1409)	0.1327	(0.1222 - 0.1431)
Manipulating egg	0.0283	(0.0239 - 0.0328)	0.0168	(0.0139 - 0.01964)
Away from nest	0.0777	(0.0550 – 0.1004)	0.0035	(0.0000 – 0.0181)

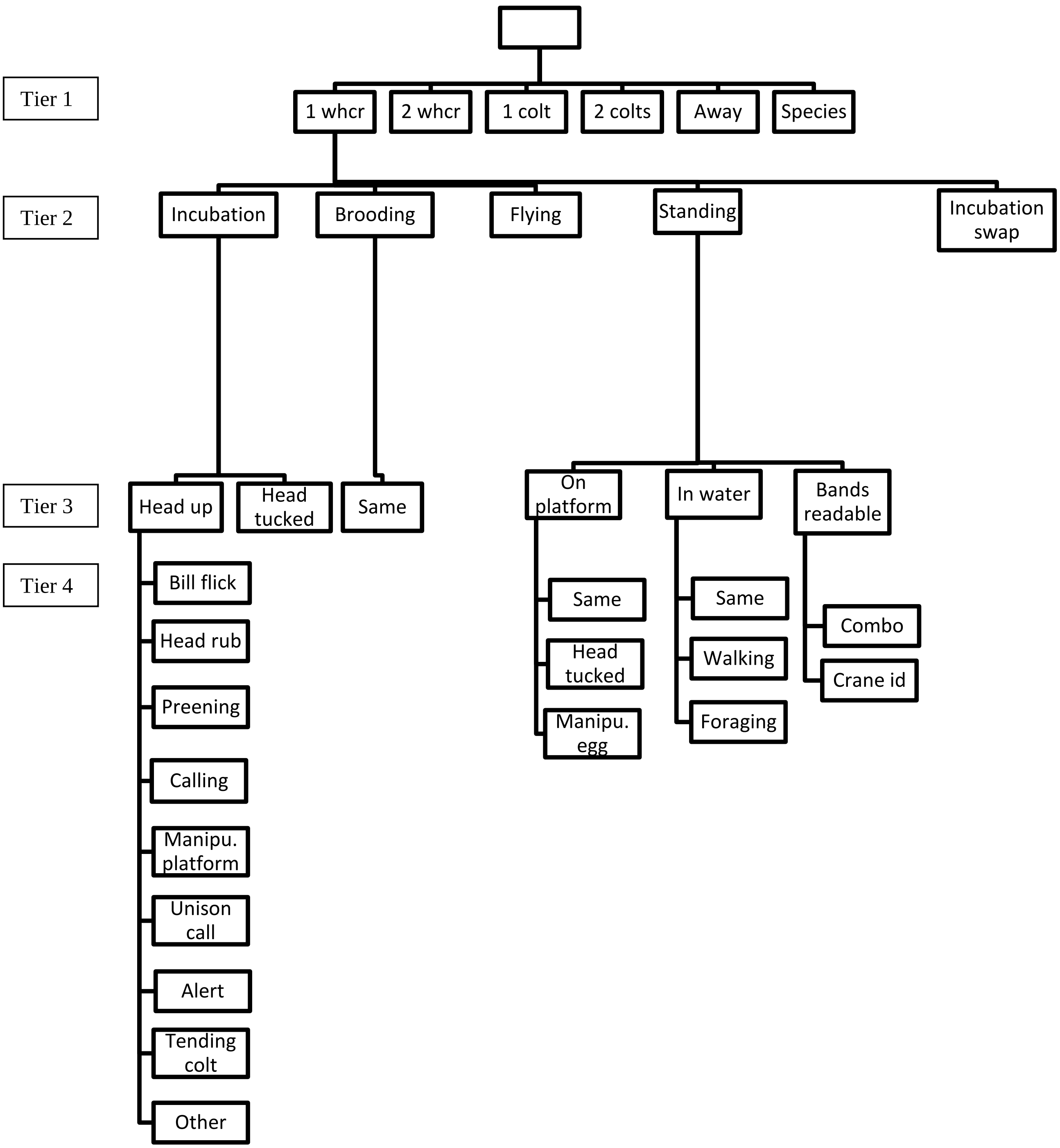
Table 2.6. Least square mean and 95% confidence interval of percent time spent in each behavior by sandhill cranes and whooping cranes.

	Sandhill Crane		**Whooping Crane**	
Incubation	0.9397	(0.9198 - 0.9595)	0.8929	(0.8724 - 0.9133)
Head up	0.7234	(0.6960 - 0.7508)	0.7822	(0.7540 - 0.8103)
Head tucked	0.2712	(0.2440 - 0.2983)	0.2163	(0.1884 - 0.2443)
Vigilance	0.4965	(0.4683 - 0.5246)	0.5926	(0.5636 - 0.6216)
Preening	0.1524	(0.1389 - 0.1658)	0.1050	(0.0911 - 0.1189)
Manipulating egg	0.0239	(0.0207 - 0.02754)	0.0212	(0.01743 - 0.0250)
Away from nest	0.0148	(0.0000 – 0.0857)	0.0664	(0.0471 – 0.0857)

Table 2.7 Least square mean and 95% confidence interval of percent time spent in each behavior by sandhill cranes with successful nests, sandhill cranes with unsuccessful nests, whooping cranes with successful nests, and whooping cranes with unsuccessful nests

	Unsuccessful Sandhill		Successful Sandhill		Unsuccessful Whooping		Successful Whooping	
Incubation	0.9189	(0.8863 - 0.9515)	0.9604	(0.9377 - 0.9832)	0.8268	(0.7916 - 0.8620)	0.9589	(0.9380 - 0.9798)
Head up	0.6996	(0.6547 - 0.7445)	0.7472	(0.7159 - 0.7786)	0.7876	(0.7391 - 0.8361)	0.7767	(0.7479 - 0.8054)
Head tucked	0.2962	(0.2517 - 0.3407)	0.2461	(0.2150 - 0.2772)	0.2103	(0.1622 - 0.2584)	0.2224	(0.1939 - 0.2510)
Vigilance	0.4594	(0.4133 - 0.5056)	0.5335	(0.5012 - 0.5657)	0.5557	(0.5059 - 0.6056)	0.6295	(0.5999 - 0.6591)
Preening	0.1440	(0.0.1219 - 0.1660)	0.1608	(0.1454 - 0.1761)	0.1054	(0.0816 - 0.1293)	0.1046	(0.0904 - 0.1187)
Manipulating egg	0.0307	(0.02466 - 0.0367)	0.0170	(0.0128 - 0.0212)	0.0259	(0.0194 - 0.0325)	0.0165	(0.0126 - 0.0204)
Away from nest	0.0282	(0.0000 – 0.0590)	0.0013	(0.0000 – 0.0228)	0.1272	(0.0939 – 0.1605)	0.0056	(0.0000 – 0.0253)

Appendix B. Flow chart of potential tags for photographs



GENERAL PROCESS

1. Name the species of crane, and number of cranes or colts in the picture. If crane is absent tag as away from nest.
2. Record the general behavior (incubation, standing, flying). Each picture with a crane in it should at least have a tag from Tier 1 and Tier 2.
3. Continue to tag using behaviors or locations from Tier 3 and Tier 4. When tagging behaviors take into account pictures before and after the picture being tagged. These other pictures can help classify the behavior.
4. If information needed to tag the photo with a behavior on Tier 4 is lacking, (for example the photo is blurry or the crane is too far away) tag with only as much detail as you can see.

INCUBATION: The crane is sitting on a nest containing eggs. If one colt has hatched but the crane is still sitting on an egg this is classified as incubation. This tag will always be followed by a tag for head up or head tucked.

INCUBATION, HEAD UP, ALERT: The cranes head is held high and its neck is fairly straight.

Incubation, head up, alert

INCUBATION, HEAD UP, OTHER: If the crane's head is low, its neck is curved, and it is not doing any of the behaviors listed this is tagged as "other."

Incubation, head up, other

INCUBATION, HEAD TUCKED: Crane's head is tucked under its wing in a sleeping position (Tacha 1987).

Incubation, head tucked

Incubation, head tucked

HEAD TUCKED VS. PREENING: Head tucked may look similar to preening. The picture on the top would be classified as incubation head up, preening. The picture on the bottom would be classified as incubation head tucked. When deciding on these behaviors look at the black and red area on the top of the crane's head. In the picture on the top, it is vertical in a preening position. In the picture on the bottom it is horizontal in a resting position.

Incubation, head up, preening

Incubation, head tucked

INCUBATION HEAD UP: If there is not enough information for you to choose a behavior do not tag photo. Only tag what you can see. The picture below are tagged as incubation, head up, but since I do not think I have enough information to decide if the crane is preening, bill flicking, manipulating platform or any other behavior I do not continue tagging.

Incubation, head up

HEAD RUB- the side or top of the crane's head is touching its back or body (Tacha 1987).

Incubation, head up, head rub

Incubation, head up, head rub

BILL FLICK: a movement blur is seen in the photo suggesting back and forth or up and down movement of bill (Whooping Crane Eastern Partnership 2012)

Incubation, head up, bill flick

PREENING - The crane's bill is touching its own body. The crane may be sitting or standing. If beak is not visible, neck will be curved toward the body, or neck will be straight and stiff with head facing down in order to preen the neck (Tacha 1987).

Incubation, head up, preening

Incubation, head up, preening

Incubation, head up, preening

Incubation, head up, preening

Incubation, head up, preening

Incubation, head up, preening

CALLING : The crane's bill is open. Head is usually tilted upward. When two cranes are in the picture and both are calling use tag "unison call."

Incubation, head up, calling

Incubation, head up, calling

UNISON CALL: This tag is only used when two cranes are visible. Both cranes are usually standing and have heads risen in vertical or almost vertical position with bill open.

Incubation, head up, unison call

MANIPULATING PLATFORM: The crane's bill is touching the nest. The crane may be stretching to grab a piece of the nest, and there may be some grass in the crane's bill. You may see a difference in the shape of the nest from one picture to another.

Incubation, head up, manipulating platform

Incubation, head up, manipulating platform

FLYING: Crane is flying, both feet off the ground.

Flying

STANDING ON PLATFORM: Crane is standing on platform.

MANIPULATING EGG: Crane is standing on platform with head down and bill touching an egg or very close to an egg.

Standing on platform, manipulating egg

SANDING IN WATER: Crane is standing in water

FORAGING: Crane is standing in the water and its beak or head is underwater or about to be underwater, or the crane has a food item in its mouth (Tacha 1987).

Standing in water, foraging

WALKING: Crane's legs are positioned one in front of the other in a walking stance.

Standing in water, walking

BANDS READABLE: If any of the color bands of a crane are visible tag picture as bands readable

COMBO: If any color bands are visible, list the bands top to bottom and left to right with a colon between legs. Use a question mark for missing bands. Cranes usually have two bands on one leg and three on the other. For example, the crane below is facing toward the camera with one wing down. The band combo would be written as rwr:gr.

Rwr:gr 13-03

CRANE ID: If enough bands are visible to id the crane, enter its WCEP id. If information is lacking leave blank. For example, in the picture below, the crane has two readable bands on its left leg. The band combo would be written as gw:???. Even though I do not have a full band combination I can assume this is 9-05 because the other crane on this nest does not have green-white on its left leg

gw:??? 9-05

TENDING COLT: Crane is facing colt and bill is very close or touching colt.

BROODING: The crane is sitting on colts only. This means that if one egg has hatched and the other has not the picture should be tagged as incubating.

N/A : There are no cranes, colts, or eggs in picture, but cranes return to the nest in subsequent pictures.

SPECIES OTHER THAN CRANE: Record all potential nest predator or mammal species visible during incubation. After the cranes have left the nest, record all animals that use the nest platform. If you are unsure of the identification of the animal, describe it. For example, the picture below (top) could be tagged as mammal. Although a Canada goose is not a nest predator, it is tagged in the picture below (bottom) because it is standing on the nest platform after the cranes have left the area.

Muskrat

Canada Goose