

1-1-2009

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Vigilance Behavior and Land Use by Sandhill Cranes (*Grus canadensis*)

By

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Thesis

Submitted to the Department of Biology

Eastern Michigan University

In partial fulfillment of the requirements

For the degree of

MASTER OF SCIENCE

In

Biology with a concentration in Organismal Biology

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May 3, 2009

Ypsilanti, Michigan

Abstract

I investigated how vigilance in sandhill crane time budgets changed with behavioral, climatic, and anthropogenic factors. I measured two different postures that could be interpreted as vigilance. Cranes significantly altered the time spent in the alert investigative posture with differences in gender and modal non-vigilant behavior. They significantly altered the time spent in the tall alert posture with differences in gender, breeding status, time of day, traffic on the nearest road, and human disturbances. The southern Michigan populations of sandhill cranes nest closer to roads and houses than they have in the past and do not preferentially avoid them. They favor emergent and semi-permanently flooded wetlands and avoid forested, open water, and scrub-shrub wetlands for nesting. They do not preferentially avoid roads and houses when selecting fall staging sites. Sandhill crane vigilance is best determined by the alert investigative posture, although this posture may include other behaviors as well. Sandhill cranes adapt well to human impacts, and their population can increase with their ability to move beyond the traditional nesting and migratory staging sites.

Introduction

Sandhill Crane Natural History

Sandhill cranes (*Grus canadensis*) are tall, wetland-nesting birds found across much of North America. There are six subspecies (Tacha et al. 1992), the largest of which (*G. c. tabida*) nests in Michigan (Walkinshaw, 1949). Cranes are omnivorous. They eat row crops, primarily corn and wheat, as well as snails, slugs, grasshoppers, worms, crayfish, small mammals, frogs, snakes, and chicks and eggs of other birds (Tacha et al., 1992). They mate for life, return to the same nesting territory every year, and often reuse the same nest sites (Walkinshaw, 1989). They nest on the ground, commonly in emergent wetlands, and make their nests out of available plant material in the immediate vicinity (Walkinshaw, 1949; Drewien, 1973; Tacha, et al., 1992). They prefer to nest in wetlands dominated by cattail (*Typha* spp.) or sedges (*Carex* spp.) (Walkinshaw, 1973).

Crows and raccoons are the most destructive predators of nest and young, though ravens, foxes, and coyotes also prey on crane eggs and young (Drewien, 1973). When ground predators are experimentally removed, crane productivity increases (Littlefield, 2003).

Cranes nest in the spring and produce two (rarely one or three) eggs per year, for which both parents share incubating duties (Walkinshaw, 1949, Drewien, 1973). Incubation is about 30 days, and in Michigan chicks typically hatch in May and June (Walkinshaw, 1949). Cranes are territorial during the nesting season, when the males

do slightly more territory maintenance and the females do slightly more parental care for the offspring (Tacha, 1988; Meine and Archibald, 1996).

As the chicks fledge, family units become less territorial and cranes form large flocks where they prepare for fall migration (Walkinshaw, 1973). This flocking behavior is called staging. These flocks roost in large wetlands at night. Cranes will fly up to 5 miles (8000 meters) from the staging wetland to forage (Provost, 1991). The Michigan population of sandhill cranes migrates to Florida and Georgia for the winter (Tacha et al., 1992). This occurs between October and December, with some individuals returning to Michigan as early as February (pers. obs.). A juvenile crane will stay with its parents for 10 months (Tacha, 1988), but Michigan cranes do not mate until they reach three years old (Walkinshaw, 1973). During these three years young cranes form non-territorial flocks of non-breeding birds; hence flocks of cranes can be found at all times of the year where cranes are present. These flocks cause some crop damage, especially to corn, although the extent of this probably varies with geographic region (Halbeisen 1980, McIvor and Conover 1994).

The Southern Michigan Sandhill Crane Population

The sandhill crane population has increased sharply in Michigan over the past 75 years following a ban on hunting. In 1931, Walkinshaw (1949) estimated that there were 17 breeding pairs in southern Michigan; by 1946 the number had increased to 27 pairs (Walkinshaw, 1949). In 1952, a more comprehensive survey found 49 breeding pairs (Walkinshaw and Wing, 1955), and by 1973, 151 pairs were found (Walkinshaw and Hoffman, 1974). In 1987, 642 pairs were known in southern Michigan (Hoffman,

1989). Although some of the increase in known pairs is likely due to greater awareness of cranes and increased effectiveness of sampling methods, without doubt the sandhill crane population of Michigan has increased sharply.

With this increase in crane population, cranes have come into increasing contact with humans. In the past it was thought that sandhill cranes avoided human presence, preferring to nest in large, isolated wetlands (Walkinshaw, 1949). Since then, cranes have increasingly bred in wetland closer to roads and houses (Hoffman, 1983).

Habitat Studies

Many studies have been conducted on sandhill crane nest site characteristics, nesting success, and general population demographics in a given region (Burke, 2001; Provost, 1991; Drewien, 1973). Likewise, there have been several studies on general habitat characteristics that may influence habitat (nesting wetland) choice (Su, 2003; Provost, 1991; Drewien, 1973). On the Michigan population, Hoffman (1983) found that between 1970 and 1982, the average nesting wetland size decreased from 58 to 38 ha, 65% of nesting wetlands were associated with open water, the distance to the nearest road decreased by 20%, and the distance to the nearest residence decreased by 26% (n = 26). While there has been some research conducted on habitat use by cranes, little research has been conducted on the habitat components of fall staging areas. Furthermore, no large-scale study of sandhill crane habitat use in the southern Michigan population has been conducted in over 25 years.

Vigilance

Vigilance is an important factor in the time budget of any animal. It is widely known that vigilance increases with increased predation risk (Bednekoff and Lima, 1998). Sandhill cranes have two postures that can be associated with acts of vigilance. In cranes these postures are defined as “alert investigative” and “tall alert,” while in geese they are called “head up” and “extreme head up” respectively (Tacha, 1988; Lazarus and Inglis, 1978). Voss (1976) also defined them as “standing/resting,” and “alert” postures. A crane standing, or rarely sitting with its head up and bill held horizontally but its neck not fully extended, characterizes the alert investigative posture. The crane is apparently looking around and may also be walking slowly during this behavior. A crane standing erect with its neck fully outstretched, presumably for a taller vantage point, characterizes the tall alert posture. This behavior is often directionally oriented, and a crane typically does not walk during this behavior. Previous investigations of the tall alert posture indicate that in cranes, it is usually directed toward a specific, known disturbance in the environment (Tacha, 1988; Voss, 1976). Tacha (1988) also notes that this behavior can be contagious in a flock.

Previous workers have disagreed on to what degree these postures are vigilance versus other purposes such as checking on young, attentiveness to other conspecifics, or scanning for food. Voss (1976) interpreted the alert investigative posture as a mere resting position with no vigilance associated with it. The tall alert posture was defined as the vigilant posture in this case. Tacha (1988) interpreted the alert investigative posture as a posture indicating that the cranes were “not obviously alarmed, but appeared inquisitive about something in the environment.” This is close to a traditional

definition of vigilance, but the wording still implies a response to a specific disturbance in the environment. The tall alert posture was interpreted as an alarmed posture used as a communication posture to alert conspecifics to danger. Research on pink-footed geese (*Anser brachyrhynchus*) interpreted the head up posture as behavior other than vigilance while the extreme head up posture was interpreted as anti-predator vigilance (Lazarus and Inglis, 1978). Based on these findings, the most probable interpretation is that the alert investigative posture exhibits traditional vigilance, as well as also other behaviors not associated with vigilance, while the tall alert posture is a reaction to a specific disturbance in the environment.

One thesis also compiled a comprehensive list of sandhill crane behaviors (Voss, 1976). Each behavior exhibited by sandhill cranes was described and illustrated. However, the frequency of each behavior and its relevance in the time budget of cranes was only lightly sampled and often limited to observations of captive birds. This was expanded on when behaviors were described under field conditions in migratory flocks in the central flyway (Tacha, 1988). No studies have been conducted on conditions that affect vigilant behavior in cranes on breeding territories. Also, very few have looked at the effects of human impacts on various aspects of crane behavior, and those that have were limited in scope. One such study was conducted during spring migration on the Platte River in Nebraska. It was found that when a car stopped on an adjacent road, cranes closer than 70 m stopped their behavior, became alert, and moved away (Burger and Gochfeld, 2001).

Hypotheses

I investigated the time budget of cranes, specifically how vigilance behaviors are affected by various spatial and temporal factors. A better understanding of what factors contribute to vigilant behavior can aid in management for a growing crane population. I also attempt to update the status of the sandhill crane population in southern Michigan. Within this I examined habitat patch use by breeding and non-breeding cranes, specifically nesting wetland use. I attempted to quantify habitat use as it relates to human impacts and wetland characteristics.

My specific aims were 1) to determine what life history, environmental, and anthropogenic factors contribute to vigilant behavior in cranes; 2) to quantify the association of and differences between the alert investigative and tall alert postures in cranes; 3) to determine what habitat features of wetlands are important in nesting wetland choice by cranes; 4) to determine what anthropogenic land use characteristics are important for wetland nesting choice by cranes; and 5) to determine what habitat characteristics are important in wetland choice for fall staging wetlands.

Materials and Methods

Study Area

During the nesting season, the study area was 145.5 square miles in northeastern Jackson County, Michigan, including Waterloo and Henrietta Townships, as well as parts of Grass Lake and Leoni Townships. This area consisted of 37% farmland, 21% upland forest, and 26% wetland (Michigan Department of Natural Resources, 2001). The farmland consisted primarily of row crops, mainly corn, soy, and wheat (pers. obs.). Some hay and dairy farming also occurred. Mean population density in the primary study area was 158 people per square mile overall, but only 82 people per square mile outside of developed residential areas. These developed residential areas in the primary study area were small and consisted mainly of the villages of Clear Lake, Grass Lake, Waterloo, Munith, and Pleasant Lake. The city of Jackson was located 3 to 15 miles from the study area; and a major Interstate highway (I-94) runs through it. Waterloo State Recreation Area comprised a major part of the study area, and much of the undeveloped land (wetland and forest) was located within the Recreation Area boundary.

Within this study area is located Haehnle Audubon Sanctuary, a sanctuary founded in 1955 specifically to protect sandhill cranes. In 2005 the large emergent marsh at the center of the sanctuary supported at least five breeding pairs of sandhill cranes, as well as a flock of non-breeding cranes. In the fall, this wetland also served as one of the primary migratory staging areas for cranes in Michigan. It had been censused for cranes periodically since 1935, with annual detailed counts posted on the Sanctuary website dating back to 1969 (Jackson Audubon Society, 2006). The primary

study area has been described extensively elsewhere (Halbeisan, 1980; Hoffman, 1983; Hoffman, 1989) and has been reported in the past to have the highest nesting density of sandhill cranes in the nation (Hoffman, 1983).

For fall staging, due to the relatively small number of fall staging locations, the primary study area was expanded to include all of Jackson County. Jackson County is located in south-central Michigan and has one major metropolitan center (Jackson). Land use in Jackson County was primarily agricultural (50%), with wetlands (21%), upland forest (20%), developed land (6%), and open water (2%) comprising the majority of the remainder of the land (Michigan Center for Geographic Information, 2002).

Wetland and Land Use Definitions

Wetland classes were defined in four categories: 1) emergent wetlands consisting of saturated soils and emergent herbaceous hydrophytes; 2) forested wetlands with woody vegetation growing above six feet; 3) scrub-shrub wetlands dominated by woody vegetation under six feet; and 4) aquatic bed and open water wetlands (combined for analysis purposes) which have deep water and possibly hydrophytes (in aquatic bed wetlands) below the surface (US Fish and Wildlife Service, 1994).

Temporarily flooded wetlands are those that are typically dry but sometimes may become saturated with water during the spring high water levels. Saturated wetlands are those where the soil is typically saturated with water for much of the growing season, but standing water is rare. Seasonally flooded wetlands are those that have standing water during the spring growing season but often dry out later in the year.

Semi-permanently flooded wetlands have standing water for most of the year, and when the water level falls the water table is still near the surface. Intermittently exposed wetlands have standing water all year during most years and only rarely dry out. Permanently flooded wetlands have standing water present all year every year (US Fish and Wildlife Service, 1994).

Land use types were combined into six categories based on National Land Cover Data categories (Michigan Center for Geographic Information, 2002). These categories are urban land use consisting of residential, industrial, and roads; farmland consisting of row crops, hay fields, pasture land and fallow open land; upland forest with trees and well aerated soil; wet forest consisting of forests with swampy saturated soils; wetlands; which include all non-forested wetland types; and open water consisting of lakes and rivers.

Behavioral Data Recording

Over the study period, I made 480 hours of field observations. To record behavioral observations, I used a digital video camera JVC model GR-D22U (700x digital zoom) whenever possible. When cranes were too far away for effective recording, a spotting telescope, watch, and pencil and paper were used to record time spent in the vigilance postures and total number of bouts for each posture. This distance was determined by the ability of the camera resolution to show the difference between the alert investigative and tall alert postures. Distance from me to the cranes ranged from 500 ft to greater than one mile. I recorded observations from my car, usually with the engine off. Approximately 6% of the observations were made on rainy

days when the weather required that I defog the windshield or run windshield wipers. These actions required running the car engine. I parked on the roadside and waited 10 to 15 minutes. During this time I counted the number of cars that passed, noted weather information, and recorded any human activity that was nearby. This time also allowed me to determine if my presence would impact vigilance. This was determined by the amount and direction of vigilance (toward me), and by the direction of crane movement away from me. The car window facing the cranes was up while the car window facing away from the cranes was usually down. This was to minimize any potential disturbance on my part while allowing me to hear noise from the environment. Video recording took place after the initial wait and lasted between 5 and 15 minutes. This variation was caused by the movement of the cranes around line-of-sight obstacles in the environment. Only continuous segments over three minutes were used, as anything under this period was suspect for rendering an accurate time budget for the cranes under those specific environmental conditions. Recordings were excluded from analysis if the cranes reacted to my presence for more than the ten-minute waiting period or moved significantly to a new part of the field to continue their activities.

Videotaped observations were later played back and analyzed. The total time in the alert investigative posture and number of times in this posture over the total recording time were measured. From this data the average length of bout and percent time in this posture were calculated. The tall alert posture was also analyzed for the same data. Average length of bout and number of bouts per minute were only analyzed when changes in percent time in a posture were significant.

Field research took place from February to December 2005. This corresponded with the first known arrival of cranes in the spring through the last known departure in the fall. During this interval I drove through the study area on average twice a week at various times of day. As cranes are territorial during the breeding season, I assumed that any paired cranes seen consistently at the same location at the same time were the same individuals.

Fall staging field study took place between the first week of September and the first week in December 2005. Although flocks of cranes were found every month of the study period, the start of the fall staging timeframe corresponds with the last time I saw paired cranes on a territory known from summer research. The end corresponds with the last time I saw cranes in the study area.

Ten factors were analyzed to determine their effects on vigilance in cranes. These factors fall into three categories. The sex of the animal, flock size, behavior, and breeding status are factors based on the biology of cranes. Time of day, time of year, ambient temperature, and sky conditions are abiotic environmental factors. Vehicle traffic on the nearest road and human disturbance are man-made factors.

As male sandhill cranes are slightly but distinctly larger than females (Tacha, et al., 1991), the larger crane in a pair was assumed to be the male for the purposes of sexual differentiation. Group size was an exact count in every case below 100 individuals. Over that it became an estimate. The observer determined the modal non-vigilant behavior of the focal crane. The breeding status of the cranes was grouped into breeding cranes with chicks present, breeding cranes without chicks, and non-breeders.

The first two categories were based on the presence of a pair of cranes on a territory. Breeding cranes with chicks were any pair seen with chicks during the breeding season. Breeding cranes without chicks were paired cranes on a territory but with no chicks. This category also included pairs with a member assumed to be incubating. Cranes were assumed to be non-breeders if there were three or more adults present through August. All cranes seen were considered non-breeders after August. The three observations made at the nest sites themselves were included under breeding cranes without chicks.

For statistical purposes, time of day was considered the minute of the day (12:00 AM: minute 1, etc.). For logistical reasons, very few observations were made prior to 11:00 AM. These were excluded from analysis. Time of year was the calendar day of the year (Jan 1: day 1, etc.). Temperature was estimated from Spring Arbor University radio (a local radio station), with a sample later cross-checked with Jackson weather station data, Weather Bureau Army Navy (WBAN) ID # 14833 available from the National Oceanic and Atmospheric Administration (NOAA). These were found to be accurate within two degrees Fahrenheit. Sky conditions were generalized into three categories: sunny skies, overcast skies, and rain. Partly and mostly cloudy skies were grouped into sunny or overcast based on how much sun was on the cranes during the video taped period. If over half of the taping session had sun shining on the cranes, it was considered "sunny." If over half of the taping session was shaded by clouds, it was considered "overcast." Skies were "rainy" if any precipitation was falling or had fallen within the past half hour.

Vehicle traffic was analyzed as the number of cars that passed on the nearest road over a ten-minute period. Human disturbance was classed into three categories: no humans present (class “0”), human presence without disturbance (class “1”) and human presence with disturbance (class “2”). Classes 1 and 2 were differentiated mainly by sound level. People walking on the nearest road or working in their garden were class 1, while shouting, playing, construction, or power tools were considered class 2. Livestock were not considered human disturbance.

Data were analyzed using JMP 3.2.1. The variables listed above were analyzed for their effects on the occurrence of the alert investigative and the tall alert postures. For sex differences the only statistical test that fit the data without violating the assumptions was the Sign Test. Analyses with continuous units were analyzed with least-squares regression. Variables with discrete units were analyzed with t-tests and Kruskal-Wallis tests as appropriate. Some data were transformed to meet assumptions of the tests. In most behavioral tests, data were grouped to remove pseudoreplicates.

Nesting Wetland Determination and Analysis

Sandhill crane pairs were located using information from a member of the Jackson Audubon Society (Ronald Hoffman, pers. comm.), by systematically searching wetlands, and by observation and tracking of cranes in the field. Systematic searching of wetlands involved scanning wetlands with binoculars or a telescope, and by audio playback of the crane unison call and listening for a response. Observation of cranes in the field involved watching a crane or family unit over a several hour period or over several days or especially in the evening. I could then determine which wetland or

wetlands the family unit used consistently. A wetland was considered part of a pairs' breeding territory if a nest was located or nesting behaviors were seen. Nesting behaviors included cranes coming and going consistently from a wetland during the nesting season, one crane seen at a time during the nesting season, but two seen later, and presence of chicks during the summer. Individuals were assumed to be the same cranes at each visit as cranes are territorial during the breeding season. A wetland was also considered part of a pair's home range when the pair was consistently seen throughout the breeding season regardless of nesting behavior or presence of chicks.

Spatial data for nesting and staging wetland analysis were analyzed using ArcView 9.0. For the purposes of analysis, land use categories were combined into urban, farmland, upland forest, water, wet forest, and wetland. Land use categories were combined based on Michigan CGI Library categories (Michigan Center for Geographic Information, 2002). The most recent file available for the study areas, the 2001 land use file for the Lower Peninsula, was clipped to the study areas. Land use surrounding home range wetlands was compared to the expected frequency of land use based on land use surrounding random wetlands within the study areas. In all cases, randomly selected wetlands were chosen by a random number generator applied to the Feature Identifier (FID) number of wetlands in ArcView. Land use was calculated for a 500 m radius surrounding spring home range wetlands and a five mile (8000 m) radius for fall staging wetlands. The proportions of each land use category were compared with overall land use proportions in the study area. These comparisons were analyzed using t-tests. Distances to nearest house and nearest road were made from the edge

of the wetland and were compared with distances from randomly selected wetlands and analyzed using the t-test. All reported errors are \pm one standard error.

Results

Crane Arrival and Departure

I first saw cranes in the spring during the first week in March 2005 and last saw them in the first week of December of the same year. A series of weather fronts went through in the last week of November and the first week of December, which likely contributed to early departure of cranes for migration south.

Effects of Sex on Vigilance

Male sandhill cranes spent significantly more time in the alert investigative posture than did females ($37.56 \pm 6.67\%$ vs. $23.84 \pm 4.50\%$, $p < 0.01$, Sign test, Graph 1). Male cranes also spent significantly more time in the tall alert posture than did females ($10.35 \pm 4.42\%$ vs. $3.73 \pm 2.01\%$, $p < 0.01$, Sign test, Graph 2). The greater time spent by males in the alert investigative posture was due to the greater length of alert investigative bout (15.96 ± 4.01 seconds vs. 7.81 ± 1.55 seconds, $p < 0.05$, Sign test, Graph 3) rather than a greater number of alert investigative bouts per minute (1.79 ± 0.20 vs. 1.73 ± 0.17 , $p < 0.10$, Sign test, Graph 4). The greater time spent by males in the tall alert posture was more obviously due to a greater length of tall alert bout (18.98 ± 5.61 seconds vs. 8.94 ± 2.80 seconds, $p < 0.05$, Sign test, Graph 5) rather than a greater number of tall alert bouts (0.35 ± 0.83 vs. 0.21 ± 0.81 , $p < 0.10$, Sign test, Graph 6).

Effects of Group Size on Vigilance

Group sizes ranged from 1 individual to 300 birds in a single field. There was no significant effect of group size on the sandhill crane alert investigative posture ($F_{1,88} = 0.21$, $p < 0.646$, Graph 7). There was also no significant effect of group size on the tall alert posture ($F_{1,87} = 2.14$, $p < 0.147$, Graph 8).

Changes in Vigilance with Crane Behavior

Crane behavior was grouped into foraging, preening, and other behaviors. Due to the limited number of “other” behaviors, these were dropped from analysis. Sandhill cranes spent significantly more time in the alert investigative posture while preening than they did when foraging ($38.17 \pm 3.34\%$ vs. $30.21 \pm 2.12\%$, $H_{154,60} = 2.51$, $p < 0.01$, Kruskal-Wallis test, Graph 9). Sandhill cranes spent somewhat more time in the tall alert posture while foraging than while preening ($4.94 \pm 1.02\%$ vs. $3.85 \pm 1.66\%$, $H_{151,60} = 1.67$, $p < 0.09$, Kruskal-Wallis test, Graph 10), but this difference is not significant. The difference in time spent in the alert investigative posture is due to a greater number of alert investigative bouts per minute while preening (1.93 ± 0.12 vs. 1.51 ± 0.07 , $H_{154,60} = 2.98$, $p < 0.01$, Kruskal-Wallis test, Graph 11) rather than more time spent in the posture per bout (23.45 ± 6.53 seconds vs. 19.55 ± 3.21 seconds, $H_{154,60} = 1.09$, $p < 0.28$, Kruskal-Wallis test, Graph 12).

Changes in Vigilance with Breeding Status

Sandhill cranes did not spend a significantly different amount of time in the alert investigative posture whether they were a breeding pair without chicks, a breeding pair

with chicks, or a non-breeding flock, including post-breeding pairs with fledged young ($30.03 \pm 6.30\%$, $29.82 \pm 5.58\%$, and $33.67 \pm 3.44\%$ respectively, $H_{13,7,19} = 1.19$, $p < 0.55$, Kruskal-Wallis test, Graph 13). Cranes spent a significantly different amount of time in the tall alert posture based on their breeding status with breeding pairs with chicks using this posture the most ($5.70 \pm 2.65\%$ without chicks, $9.89 \pm 2.03\%$ with chicks, and $3.46 \pm 1.82\%$ for non-breeders, $H_{13,6,19} = 8.87$, $p < 0.01$, Kruskal-Wallis test, Graph 14). This was due to the significantly greater number of tall alert bouts per minute by breeding cranes with chicks than breeding cranes without chicks, or non-breeders (3.57 ± 0.76 vs. 1.14 ± 0.28 for pairs without chicks and 0.33 ± 0.12 for non-breeders, $H_{13,6,19} = 17.18$, $p < 0.01$, Kruskal-Wallis test, Tukey-Kramer HSD test, Graph 15). The difference in length of tall alert bout was not significant across the breeding classes (8.89 ± 3.89 seconds for pairs without chicks, 10.14 ± 3.19 seconds for pairs with chicks, and 6.54 ± 3.46 seconds for non-breeders, $H_{13,6,19} = 5.21$, $p < 0.07$, Kruskal-Wallis test, Graph 16).

Effects of Time of Year on Vigilance

Sandhill cranes exhibit a trend toward increasing the time spent in the alert investigative posture, both in a linear ($F_{1,34} = 3.94$, $p < 0.06$, Graph 17) and exponential ($F_{2,33} = 2.73$, $p < 0.08$, graph 17) way over the course of a year. Sandhill cranes exhibit a trend toward decreasing the time spent in the tall alert posture ($F_{1,34} = 1.14$, $p < 0.29$, Graph 18) over a year. However, none of these trends are statistically significant.

Effects of Time of Day on Vigilance

Due to the limited number of morning readings, they were excluded from analysis and only data taken after noon was used. Sandhill cranes do not appear to vary the amount of time spent in the alert investigative posture over the course of a day ($F_{1,77} = 0.07$, $p < 0.790$, Graph 19). Cranes decrease the amount of time in the tall alert posture over the course of a day. A linear decrease is significant ($F_{1,76} = 8.89$, $p < 0.004$, $r^2 = 0.11$, Graph 20); however, it involves nonsense values when used as a predictive model, since the slope of the line passes below 0% time spent in the tall alert posture. A better fit is an exponential fit ($F_{2,75} = 11.18$, $p < 0.01$, $r^2 = 0.23$, Graph 20), which shows a decrease in the tall alert posture from noon until 5:30pm, followed by an increase from 5:30pm until sunset. Cranes alter the amount of time spent in the tall alert posture by changing the number of tall alert bouts per minute over the course of a day. This is true for a linear decrease in number of bouts ($F_{1,76} = 6.64$, $p < 0.012$, $r^2 = 0.08$, Graph 21), as well as an exponential curve ($F_{2,75} = 4.57$, $p < 0.013$, $r^2 = 0.11$, Graph 21) which shows a decrease in the number of tall alert bouts until 6:00pm, followed by an increase in bouts leading up to sunset. As with percent time in the tall alert posture, the linear fit is a nonsense model as the predictive best fit line drops below 0 bouts per minute. A better fit is the exponential fit, which shows that cranes decrease the number of times in the tall alert posture per minute through the afternoon, followed by an increase in the evening. Cranes do not significantly change the length of tall alert bout over the course of a day ($F_{1,76} = 1.84$, $p < 0.179$, Graph 22).

Effects of Temperature on Vigilance

While sandhill cranes do appear to decrease the amount of time spent in the alert investigative posture with increasing temperature, this decrease is not significant ($F_{1,25} = 2.77$, $p < 0.109$, Graph 23). Likewise, while cranes decrease the amount of time spent in the tall alert posture with increasing temperature, this decrease is not significant ($F_{1,24} = 0.13$, $p < 0.73$, Graph 24).

Effects of Sky Conditions on Vigilance

Sandhill cranes do not significantly change the amount of time spent in the alert investigative posture with a change in sky conditions ($29.47 \pm 3.13\%$ for sunny skies, $34.63 \pm 4.52\%$ for cloudy skies, and $43.62 \pm 14.86\%$ for rain, $H_{44,32,5} = 1.05$, $p < 0.59$, Kruskal-Wallis test, Graph 25). They also do not significantly change the amount of time spent in the tall alert posture with changing sky conditions ($5.95 \pm 1.79\%$ for sunny skies, $7.60 \pm 2.53\%$ for cloudy skies, and $1.91 \pm 1.91\%$ for rain, $H_{43,32,5} = 1.75$, $p < 0.42$, Kruskal-Wallis test, Graph 26).

Effects of Automotive Traffic on Vigilance

The number of cars that passed by on the nearest road over a 10-minute period was log transformed. Sandhill cranes do not change the amount of time in the alert investigative posture with an increase in traffic levels on the nearest road ($F_{1,68} = 0.06$, $p < 0.814$, Graph 27). They do decrease the amount of time spent in the tall alert posture with an increase in traffic on the nearest road ($F_{1,67} = 5.50$, $p < 0.022$, $r^2 = 0.08$, Graph 28). This is due to a decrease in the length of tall alert bout cranes spend in the posture

($F_{1,67} = 4.81$, $p < 0.032$, $r^2 = 0.07$, Graph 29), rather than a decrease in the number of tall alert bouts per minute ($F_{1,67} = 3.82$, $p < 0.055$, Graph 30).

Effects of Human Disturbance on Vigilance

Sandhill cranes do not change the amount of time spent in the alert investigative posture with changing human disturbance levels ($30.33 \pm 2.77\%$ with no disturbance, $36.02 \pm 8.52\%$ with low disturbance levels, and $33.71 \pm 4.82\%$ with high disturbance, $H_{68,13,9} = 0.98$, $p < 0.61$, Kruskal Wallis test, Graph 31). They change the amount of time spent in the tall alert posture with a change in human disturbance.

The greatest increase in the tall alert posture occurs with high human disturbance ($5.38 \pm 1.43\%$ with no human disturbance, $4.43 \pm 3.55\%$ with low disturbance, and $11.06 \pm 4.23\%$ with high disturbance, $H_{67,13,9} = 6.50$, $p < 0.04$ Kruskal-Wallis test, Graph 32). This is due to both an increase in number of tall alert bouts per minute (0.19 ± 0.04 with no human disturbance, 0.11 ± 0.05 with low disturbance, and 0.35 ± 0.09 with high disturbance, $H_{67,13,9} = 6.56$, $p < 0.04$, Kruskal-Wallis test, Graph 33) and an increase in the length of tall alert bout (8.39 ± 2.70 seconds with no human disturbance, 4.62 ± 2.57 seconds with moderate disturbance, and 14.03 ± 6.08 seconds with high disturbance, $H_{67,13,9} = 6.77$, $p < 0.03$ Kruskal-Wallis test, Graph 34).

Nesting Wetlands

Nesting wetlands were significantly larger than random non-crane wetlands (23.64 hectares compared with 2.73 hectares, $p < 0.01$). Cranes also selected emergent marshes at a greater frequency than expected but selected forested, open

water, and scrub-shrub wetlands less than expected ($p < 0.01$, Table 2).

Hydrologically, cranes selected semi-permanently flooded wetlands at a greater frequency than expected, permanently flooded, saturated and seasonally flooded wetlands in proportion with available wetlands, and intermittently exposed and temporarily flooded wetlands less than expected ($p < 0.03$, table 3). Cranes did not nest significantly farther away from roads ($F_{1,96} = 0.40$, $p < 0.53$, Graph 35) or from houses than expected ($F_{1,96} = 0.004$, $p < 0.95$, Graph 36). Land use within 500 m of nesting wetlands had more wetlands ($p < 0.01$) than expected and less urban ($p < 0.01$), farmland ($p < 0.01$), wet forest ($p < 0.01$) and upland forest ($p < 0.04$) than expected. There was not a significantly greater amount of open water ($p < 0.08$) than expected.

Staging Wetlands

Staging wetlands were significantly larger than the average wetland size within the study area (393982 m^2 compared with 29696 m^2 , $p < 0.01$). Sandhill cranes do not stage significantly closer to roads ($F_{1,10} = 3.07$, $p < 0.11$, Graph 37) or to houses than expected ($F_{1,10} = 2.60$, $p < 0.138$, Graph 38). Sample size was too small for results for wetland class or hydrology to be meaningful. Land use within 5 miles of staging wetlands had less urban ($p < 0.01$) land use than expected. There was not significantly less farmland than expected ($p < 0.09$) and not significantly more wetland ($p < 0.05$) upland forest ($p < 0.05$), water ($p < 0.13$), or wet forest ($p < 0.08$) than expected.

Discussion

Vigilance

That male cranes spend more time in the alert investigative and tall alert postures is consistent with previous findings and with other aspects of crane life history. It has been previously reported that males spent more time in alert investigative posture than females (Voss, 1976; Tacha, 1988). My numbers are higher than those reported for the alert investigative posture (37% vs. 27% and 11% for males, 23% vs. 20% and 2% for females). This is consistent with the interpretation that vigilance is included in but not the exclusive behavior associated with the alert investigative posture (Tacha, 1988). The numbers reported by Voss (1976) are based on observations in a remote area in Wisconsin, with no human-related disturbances present. Both my numbers and those reported by Voss (1976) are higher than those reported by Tacha (1988). This may be due to several factors. First, the birds in Tacha's study were in large migratory flocks in the central flyway. The extremely large flock size and non-territorial status of these animals may reduce the need for vigilance. Second, any differences in what is considered "alert" could alter the results. I included all postures with a raised head to be the alert investigative posture, while Tacha seems to distinguish between a "loafing" posture and the alert investigative posture although the differences are not described or quantified. Males defend territories and young (Tacha, 1988; Meine and Archibald, 1996) and would therefore spend more time in vigilance than females. When cranes notice a disturbance, this would affect all cranes regardless of gender, thus the number of bouts would not be different but the length of time spent in the tall alert posture would be different between males and females.

A flock size effect on vigilance postures was not found. This may be consistent with the interpretation that the alert investigative posture is used for more than just vigilance, while the tall alert posture is used in response to a specific known disturbance. Assuming that a disturbance cranes will notice will occur regardless of the number of birds present, a large number of cranes will exhibit the tall alert posture. Also, many times the two postures were not directed at an outside disturbance but at other cranes (Tacha, 1988; pers. obs.). Thus, group size would not correlate with the frequency of the alert postures. It is even possible that a larger group size would lead to an increase in the alert postures.

The greater occurrence in the alert investigative posture when preening compared with foraging is probably due to the nature of preening. When an animal forages, it can still hear and see the environment without devoting time exclusively to vigilance (Cresswell et al., 2003). Preening, however, requires a crane to rub its bill around its body with its eyes and ears averted and is less likely to notice a predator if one is present. Therefore, it needs to raise its head on a regular basis to maintain an awareness of the environment. This interpretation is supported by the results that the reason for the increase in vigilant behavior while preening is due to a greater number of alert investigative bouts, rather than a greater length of bout when foraging. One potential problem with this interpretation is that birds may preen at places and times of low disturbance. Thus, lower vigilance while preening than while foraging could also be expected. That there is no significant difference in the time spent in the tall alert posture is also consistent with the interpretation of this behavior. When a disturbance is present, a crane will be alerted to it regardless of what it was doing otherwise. Despite

the lack of statistical significance, however, the difference in time spent in the tall alert posture is worthy of further investigation.

Although post hoc tests could not determine it statistically, I suspect that families with chicks were significantly more alert than families without chicks and non-breeding cranes. If this is true, then the best interpretation seems to be that cranes are more sensitive to disturbances with their offspring present than they otherwise would be (Alonzo and Alonzo, 1993). They are not more vigilant with chicks than without if vigilance is defined by the alert investigative posture, but if this posture includes behaviors other than vigilance; then pairs without chicks and flocks would use it for these purposes and the lack of increased alert investigative posture may not be inconsistent. Cranes with chicks seem to have more tall alert bouts than those without, although again this could not be confirmed statistically by post hoc testing. If this is true, it supports the interpretation that cranes are more “skittish” with chicks present and respond to lesser disturbances with the tall alert posture that they would otherwise overlook. All of this is inconsistent with research done in migratory flocks that found that pairs did spend more time in alert investigative posture than non-breeders within the flocks (Tacha, 1988). This was true regardless of the presence of chicks with the pairs (which would have been 8-10 months old by then).

There is nothing inherent in the time of year by itself that could make cranes alter their behavioral time budget, but I consider it possible that if a time of year effect exists, it could be due to a behavioral change across a year. This would be a combination of factors including a larger frequency of larger flocks (Alonzo and Alonzo, 1993), fledged young (Tacha, 1988), and a cessation of territorial behavior (Walkinshaw, 1949). As it

is, the effect of time of year on the alert investigative posture is close to significant. If a true correlation exists, it would likely be due to the above factors.

Cranes are crepuscular (Walkinshaw, 1973) and the data relating time of day to vigilance is largely consistent with this aspect of crane behavior. The lack of difference in the alert investigative posture could be due to two factors. It may be that cranes are vigilant across the day at a consistent rate. This is true if the potential for a threat exists at all times of day equally. It is also possible that there is a difference that I was unable to detect due to the lack of quality morning data. I consider this less likely because a difference was detected in the tall alert posture. The difference in the tall alert posture is due to a decrease in the number of times spent in the posture in the afternoon hours, which fits the interpretation that it relates to the crepuscular activity of the cranes. It may be that when a potential threat is noticed, it takes a stronger stimulus to make the cranes react with the tall alert posture in the mid-afternoon than at mid-day or in the evening. Also, with limited morning data, it is possible that they are more active early and become less active as the day goes on.

The lack of temperature effect on either posture is mildly surprising because I noted that cranes are generally less active when the weather is hotter. However, assuming that a threat exists no matter how warm or cold it is, a crane would be vigilant at any time. Also, if cranes notice a threat, it would elicit a tall alert response at any temperature. Cranes may also use microenvironmental conditions to offset ambient temperature by spending more time in the shade on hotter days (pers. obs.). It may also be that the alert investigative posture includes loafing behavior (Voss, 1976), in

which case a decrease in vigilance with increased temperature is offset by an increase in loafing.

Similar to the lack of temperature effect, I attribute the lack of influence on the alert investigative posture by the weather conditions to the interpretation that the posture exhibits more behaviors than just vigilance (Voss, 1976). When raining, I would expect less time spent in vigilance but more time loafing, with these effects canceling out in the amount of time spent in the posture. Even though the difference was not significant, the amount of time spent in this posture did increase with rainfall. A larger sample size may increase the power of the test and reveal a significant difference. For the tall alert posture, if less time is spent in vigilant behavior then it is probable that either fewer disturbances would be noticed or a larger disturbance would be required to elicit a tall alert response. The time spent in tall alert posture did decrease with rainfall, but not significantly. Again, I propose that a larger sample size would show that a significant difference would exist between time spent in tall alert posture when it is raining than under other sky conditions.

The decrease in time spent in the tall alert posture with increasing traffic is due to shorter bouts rather than a decreased number of bouts. I interpret this to mean that cranes can adapt to traffic on the roads without disruption to their daily life, and even when aroused into the tall alert posture, they are less sensitive to excess noise and disturbance caused by traffic.

Human disturbance levels only have a significant impact on the tall alert posture. This is important because it demonstrates that cranes can adapt to human presence. Even with heavy human disturbance, it appears that cranes will not increase their time

in the alert investigative posture. Although it could not be demonstrated statistically, I suspect that the increase in the tall alert posture occurs only in situations of high human disturbance (my disturbance level “2”). If this is the case, it means that a low level of human disturbance (people present but without excessive noise) does not upset cranes.

To follow up on this study, the difference between standing/resting (Voss, 1976) and true vigilance, and any other behavior that is exhibited by the alert investigative posture, needs to be determined. Descriptions of these behaviors need to be clarified so that future researchers can distinguish the difference between them. From there, the time budget of cranes can be determined, separating loafing from vigilance so that an accurate picture of determinants of crane vigilance can be developed. Specific stimuli can also be tested to determine their effects on vigilance. I made no attempt to determine what stimuli contributed to the postures in question, although in many cases I could determine specific causes of the tall alert posture. Regarding human disturbance specifically, the types of disturbance need to be assessed for their effects on vigilance. For instance, many of the class “2” disturbances were related to sound rather than a visual stimulus. This raises the question as to which sounds and what level of sound are needed to increase vigilance in cranes. Also, how close to the disturbance do cranes have to be to increase vigilance? Most important, what impact does increased vigilance have on productivity? This is the ultimate determination of how disruptive humans can be before negatively impacting the crane population.

Also, I was unable to statistically determine which combinations of factors play a part in influencing crane vigilance postures. I attempted to analyze six of the factors (flock size, time of day, time of year, weather, traffic, and human disturbance) using

multivariate statistics to quantify how they may work together to influence vigilance. Although I was unable to produce a definitive statistical model, it appears that each of the six factors does play some part in crane time budgets when analyzed together in some combination. This type of effect is known in the mountain gazelle (*Gazella gazella*), where human disturbance, group size, and vigilance are correlated (Manor and Saltz, 2003).

Other follow-up studies related to this research include increasing the sample size to determine if cranes with chicks really do increase vigilance over pairs without offspring and non-breeders. Also, it still needs to be determined if rainfall decreases vigilance, or if cranes spend a similar proportion of time in the alert investigative posture as a loafing posture, or both.

Nesting Wetlands

The ideal wetland for nesting sandhill cranes still seems to be a large, emergent wetland, somewhat isolated from human presence, with standing water that isn't too deep and somewhat isolated from human presence (Walkinshaw, 1949; Hoffman, 1983). However, with an increasing crane population, these wetlands are occupied and cranes are adapting to wetlands that do not fit all criteria.

The last reported average nesting wetland size for this study area was 320000 m² in 1983 (Hoffman, 1983). The findings of this study show a 26% drop over the 22 years since then, but the wetlands in use are still much larger than the average available wetland. The distance to the nearest road dropped by 64% and the distance to the nearest residence dropped by 46% over the same period. This may be due to the

spread of humans with roads and houses closer to traditional wetlands, or an increasing crane population selecting wetlands closer to extant roads and houses. I suspect both contribute to the trend. Although I made no attempt to determine nesting density in the study area, Hoffman (1983) found a strong negative correlation between crane density and these wetland characteristics. I suspect this correlation holds true still.

Even though cranes often forage in farm fields, especially corn, wheat, and hay, the wetlands chosen by cranes still have less farmland than expected within 500 m. This implies that farmland is not yet a limiting factor in crane breeding density (Halbeisan, 1980). Contrary to Hoffman's (1983) findings, I did not find that cranes nested significantly closer to open water than expected. This difference may be due to the resolution of the land use analysis, as many of the nesting wetlands had small areas of open water within them. It is also possible that the fact that nesting wetlands were chosen with less farm, forest, and wet forest than expected is due to the nature of land patterns in the study area. Farmland, wetlands, and forests each tend to be clustered together within northeast Jackson County. This is partly due to the presence of Waterloo State Recreation Area, where forests tend to be clustered heavily. This clustering means that it is difficult to determine whether cranes select wetlands due to their proximity to other wetlands or simply because that is where more of the wetlands are.

The lack of difference between crane wetlands and non-crane wetlands regarding distances to house and road are consistent with the hypothesis that cranes are less concerned with small-scale human impacts and more concerned with other wetland features such as vegetation, water access, and hydrology. It is more likely that

cranes are sensitive to large-scale human impacts but can tolerate low levels of disturbance.

To follow up on this study, a detailed population census is overdue for southern Michigan sandhill cranes. Also, the variables measured in this study need to be re-analyzed with specific nest sites located rather than with nesting wetlands. With specific nests located, the microhabitat of the wetlands can be looked at to determine where within these wetlands cranes are nesting. Also, I was not successful in determining productivity of crane pairs during the breeding season. I suspect that cranes are actually more successful at raising chicks in wetlands that are more isolated from each other and nearer farmland than those with higher crane density. I could not quantify this because my sample is unlikely to be random and more likely biased to those cranes more easily located.

Staging Wetlands

As I located only six staging wetlands in Jackson County, the results should be interpreted with caution. Five of the six wetlands used for staging are either open water or adjacent to open water during the spring. However, in fall during the staging season the water level has dropped so that they are often shallow with emergent vegetation present (pers. obs.). Although the wetlands used for staging have less urban land within 5 miles of them than expected, they are not farther from roads or houses than random non-staging wetlands. The means for distance to roads and houses are actually quite (although not significantly) smaller than the means for the non-staging wetlands. If an increased sample size increased the power of this test to make the

difference significant, I do not believe that it would mean that cranes prefer to be closer to roads and houses. Rather, it would be likely that larger wetlands are closer to roads and houses by virtue of their size alone. What this does demonstrate is that while staging, cranes can tolerate some human presence without disrupting their life history, continuing the trend noticed by Hoffman (1983).

Also important is the result that cranes do not select staging wetlands based on their proximity to farmland within the daily foraging radius. Farmland is an excellent food source for cranes during their preparation for migration when they are building up their energy reserves (Tacha et al., 1987). Because they do not preferentially stage near farmland, it shows that there are more farms present than cranes to take advantage of them and that farmland is not a population-limiting factor for cranes or that it is not a deciding factor for staging wetland choice.

The variables studied in this thesis need to be re-analyzed with a larger sample size of staging wetlands. Also, which cranes (geographically) choose which staging area? I also noticed that some small groups of cranes, probably family units (Tacha, 1988), roosted in small wetlands near but distinct from staging wetlands. I do not believe these cranes nested in these wetlands during the breeding season. It remains to be determined if these cranes later join the large flocks in the staging wetlands and how long they stay in these small wetlands. No attempt was made to determine nesting success within the study area.

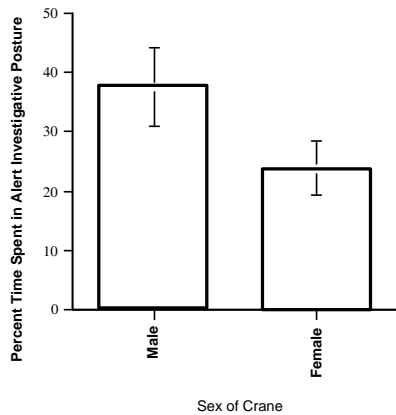
Human Impacts

Cranes nest nearer to houses and roads than ever (Hoffman, 1983). They do not demonstrably avoid them, and may even stage nearer houses and roads than expected. This indicates that individual humans tolerant of their presence do not disturb them. However, large-scale disturbances such as developed urban areas, or even small but noisy disturbances such as a house construction site, can upset cranes. Taken together, the effects of human impacts on vigilant behavior and the land use associated with nesting and staging wetlands shows that cranes can adapt to low levels of human presence.

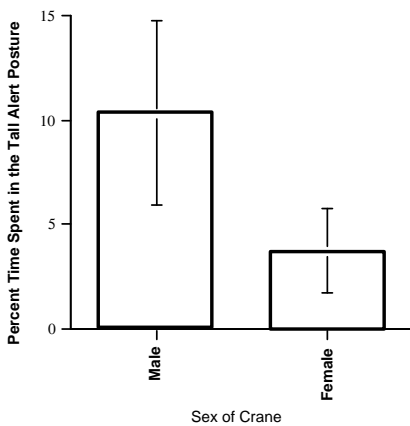
Tables and Graphs

<u>Factor</u>	<u>Alert Investigative</u>	<u>Tall Alert</u>
Sex	Yes, length of bout	Yes, length of bout
Group Size	No	No
Behavior	Yes, number of bouts	No
Breeding Status	No	Yes, number of bouts
Time of Year	No	No
Time of Day	No	Yes, number of bouts
Temperature	No	No
Sky Conditions	No	No
Traffic	No	Yes, length of bout
Human Disturbance	No	Yes, number of bouts, length of bout

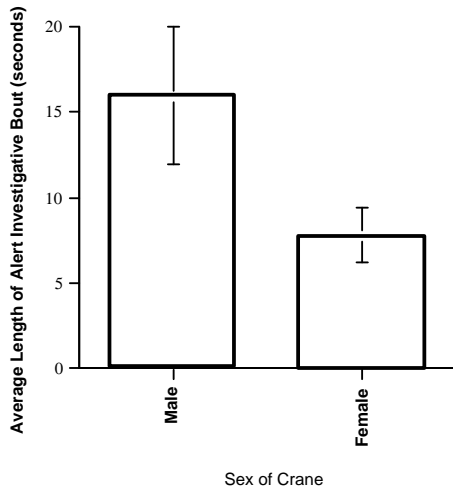
Table 1 – Summary Table for Effects of Environmental Factors on Vigilance Postures



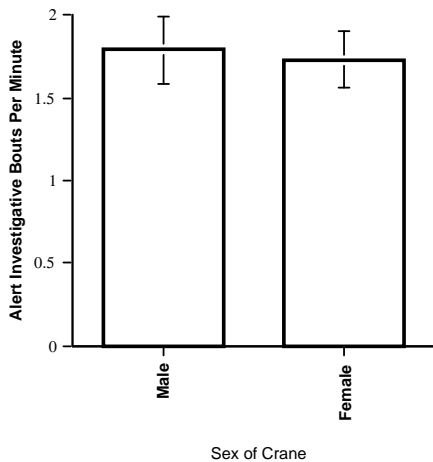
Graph 1 – Effects of Crane Gender on the Percent Time Spent in the Alert Investigative Posture. The percent time of their time budget each gender of sandhill crane spent in the alert investigative posture. Male cranes spent $37.56 \pm 6.67\%$ time in the Alert Investigative posture while females spent $23.84 \pm 4.50\%$ time in the Alert Investigative posture. Sample size: 21. This difference is statistically significant ($p < 0.01$). Data grouped by pair to remove pseudoreplicates.



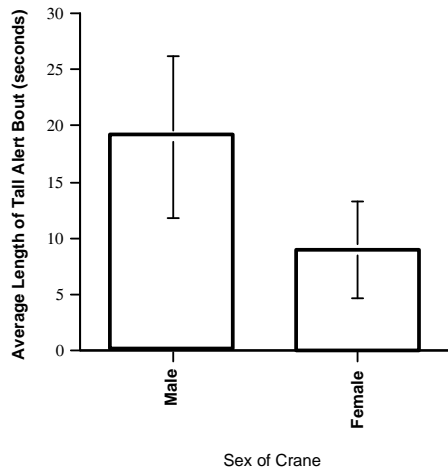
Graph 2 – Effects of Crane Gender on the Percent Time Spent in the Tall Alert Posture. The percent time of their time budget each gender of sandhill crane spent in the tall alert posture. Male cranes spent $10.35 \pm 4.42\%$ time in the Tall Alert posture while females spent $3.73 \pm 2.01\%$ time in the Tall Alert posture. Sample size: 21. This difference is statistically significant ($p < 0.01$). Data grouped by pair to remove pseudoreplicates.



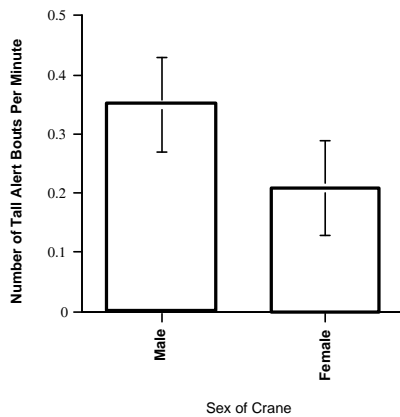
Graph 3 – Effects of Crane Gender on the Average Length of Alert Investigative Bout. The average length of time spent in the alert investigative posture by each gender of crane. Male cranes spent 15.96 ± 4.01 seconds in each Alert Investigative bout while female cranes spent 7.81 ± 1.55 seconds in each Alert Investigative bout. Sample size: 21. This difference is statistically significant ($p < 0.05$). Data grouped by pair to remove pseudoreplicates.



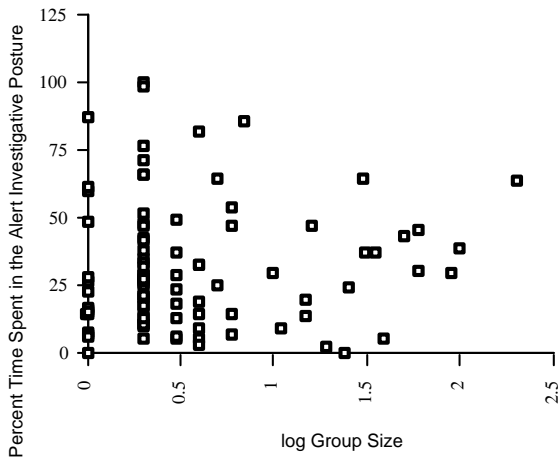
Graph 4 – Effects of Crane Gender on the Number of Alert Investigative Bouts. The number of alert investigative bouts each gender of crane spent per minute. Male cranes had 1.79 ± 0.20 Alert Investigative bouts per minute, while female cranes had 1.73 ± 0.17 Alert Investigative bouts per minute. Sample size: 21. This difference is not statistically significant ($p < 0.10$). Data grouped by pair to remove pseudoreplicates.



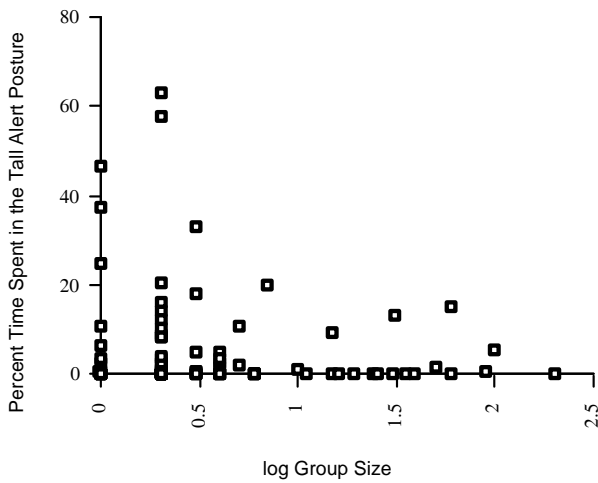
Graph 5 – Effects of Crane Gender on the Average Length of Tall Alert Bout. The average length of time spent by each gender of crane in the alert investigative posture. Male cranes spent 18.98 ± 7.13 seconds in each tall alert bout while female cranes spent 8.94 ± 4.27 seconds in each tall alert bout. Sample size: 21. This difference is statistically significant ($p < 0.05$). Data grouped by pair to remove pseudoreplicates.



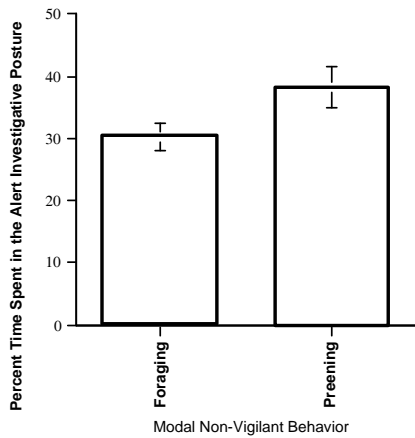
Graph 6 – Effects of Crane Gender on the Number of Tall Alert Bouts. The number of alert investigative bouts each gender of crane spent per minute. Male cranes had 0.35 ± 0.08 Tall Alert bouts per minute while female cranes had 0.21 ± 0.08 Tall Alert bouts per minute. Sample size: 21. This difference is not statistically significant ($p < 0.10$). Data grouped by pair to remove pseudoreplicates.



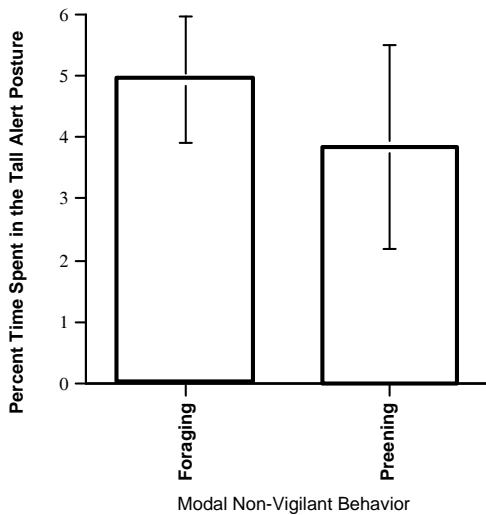
Graph 7 – Effects of Group Size on the Percent Time Spent in the Alert Investigative Posture. Sandhill cranes do not significantly change the amount of time spent in the alert investigative posture with a change in group size. $F_{1,88} = 0.21, p < 0.646$.



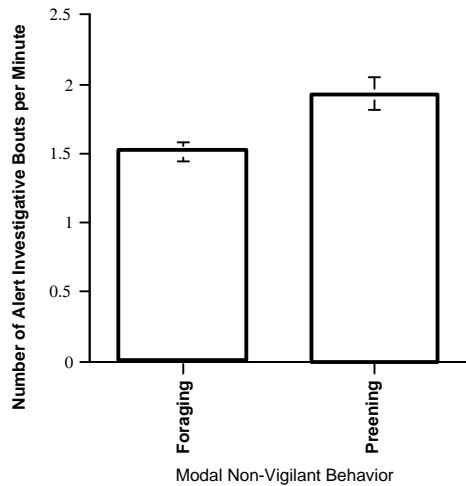
Graph 8 – Effects of Group Size on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes do not significantly change the amount of time spent in the alert investigative posture with a change in group size. $F_{1,87} = 2.14, p < 0.147$



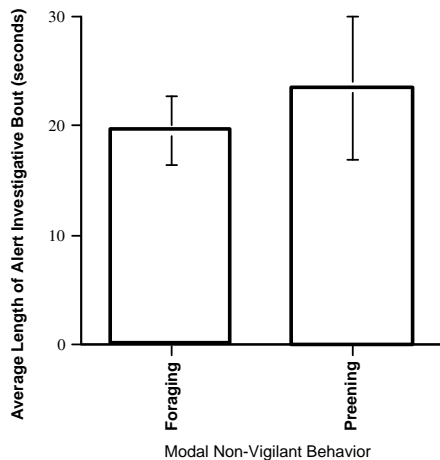
Graph 9 – Effects of Non-Vigilant Behavior on the Percent Time Spent in the Alert Investigative Posture. Sandhill Cranes spent a significantly greater amount of time in the alert investigational posture while preening than while foraging. They spent $30.21 \pm 2.12\%$ of their time in the alert investigative posture while foraging. They spent $38.17 \pm 3.34\%$ of their time in the alert investigative posture while preening. $H_{154,60} = 2.51$, $p < 0.01$, Kruskal-Wallis test.



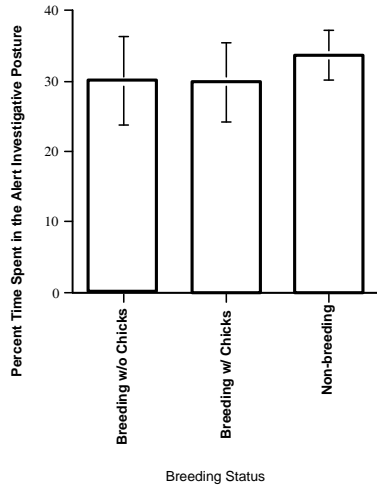
Graph 10 – Effects of Non-Vigilant Behavior on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes did not spend a significantly greater amount of time in the tall alert posture while foraging than while preening. They spent $4.94 \pm 1.02\%$ of their time in the tall alert posture while foraging. They spent $3.85 \pm 1.66\%$ of their time in the tall alert posture while preening. $H_{151,60} = 1.67$, $p < 0.09$, Kruskal-Wallis test.



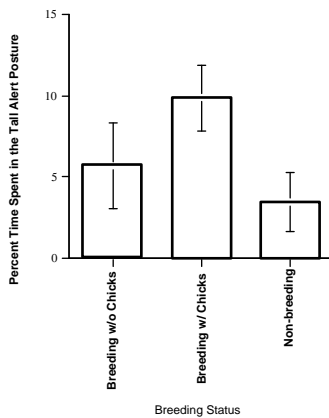
Graph 11 – Effects of Non-vigilant Behavior on the Number of Alert Investigative Bouts. Sandhill cranes had a significantly greater number of alert investigative bouts per minute while preening than while foraging. They had 1.51 ± 0.07 alert investigative bouts per minute while foraging. They had 1.93 ± 0.12 alert investigative bouts per minute while preening. $H_{154,60} = 2.98$, $p < 0.01$, Kruskal-Wallis test.



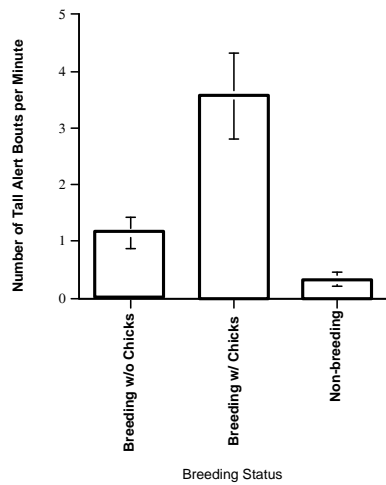
Graph 12 – Effects of Non-vigilant Behavior on the Average Length of Alert Investigative Bout. Sandhill cranes did not spend a significantly greater length of alert investigative length of alert investigative bout while preening than while foraging. They spent 19.55 ± 3.21 seconds in each alert investigative bout while foraging. They spent 23.45 ± 6.53 seconds in each alert investigative bout while preening. $H_{154,60} = 1.09$, $p < 0.28$, Kruskal-Wallis test.



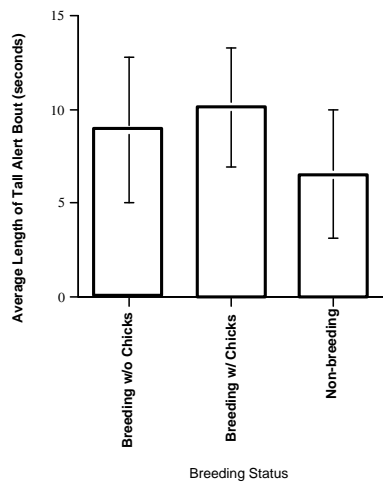
Graph 13 – Effects of Breeding Status on the Percent Time Spent in the Alert Investigative Posture. Sandhill cranes do not significantly vary the amount of time spent in the alert investigative posture with their breeding status. Breeding cranes without chicks spent $30.03 \pm 6.30\%$ of their time in the alert investigative posture. Breeding cranes with chicks spent $29.82 \pm 5.58\%$ of their time in the alert investigative posture. Non-breeding cranes spent $33.67 \pm 3.44\%$ of their time in the alert investigative posture. $H_{13,7,19} = 1.19$, $p < 0.55$, Kruskal-Wallis test. Data grouped by pair to remove pseudoreplicates.



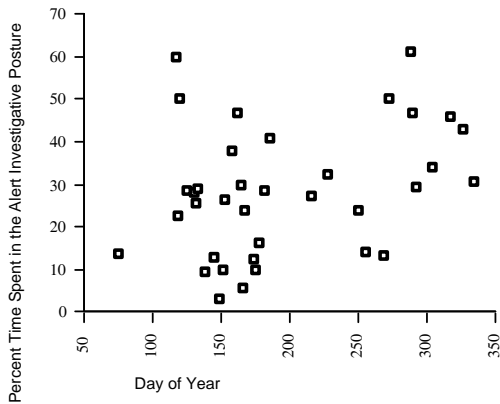
Graph 14 – Effects of Breeding Status on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes significantly alter the amount of time spent in the tall alert posture with their breeding status. Breeding cranes without chicks spent $5.70 \pm 2.65\%$ of their time in the tall alert posture. Breeding cranes with chicks spent $9.89 \pm 2.03\%$ of their time in the tall alert posture. Non-breeding cranes spent $3.46 \pm 1.82\%$ of their time in the tall alert posture. $H_{13,6,19} = 8.87$, $p < 0.01$, Kruskal-Wallis test. Data grouped by pair to remove pseudoreplicates.



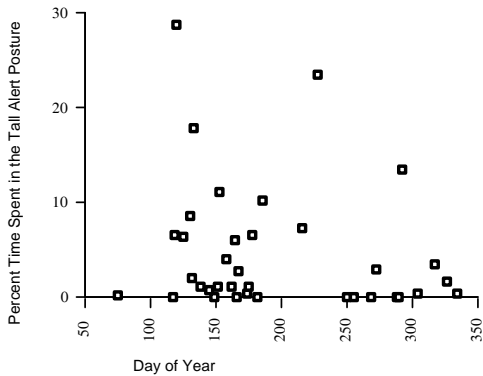
Graph 15 – Effects of Breeding Status on the Number of Tall Alert Bouts. Breeding cranes with chicks had a significantly greater number of tall alert bouts per minute than did breeding cranes without chicks or non-breeders. Breeding cranes without chicks had 1.14 ± 0.28 tall alert bouts per minute. Breeding cranes with chicks had 3.57 ± 0.76 tall alert bouts per minute. Non-breeding cranes had 0.33 ± 0.12 tall alert bouts per minute. $\chi^2_{6,19} = 17.18$, $p < 0.01$, Kruskal-Wallis test, Tukey-Kramer HSD test. Data grouped by pair to remove pseudoreplicates.



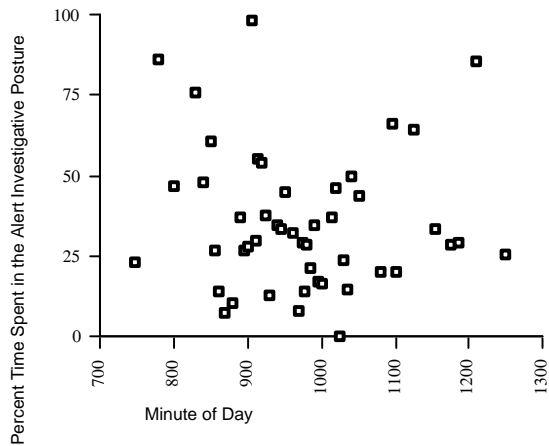
Graph 16 – Effects of Breeding Status on the Average Length of Tall Alert Bout. Sandhill cranes did not significantly alter the length of time spent in the tall alert posture across breeding classes. Breeding sandhill cranes without chicks spent 8.89 ± 3.89 seconds per tall alert bout. Breeding sandhill cranes with chicks spent 10.14 ± 3.19 seconds per tall alert bout. Non-breeding sandhill cranes spent 6.54 ± 3.46 seconds per tall alert bout. $H_{13,6,19} = 5.21$, $p < 0.07$, Kruskal-Wallis test. Data grouped by pair to remove pseudoreplicates.



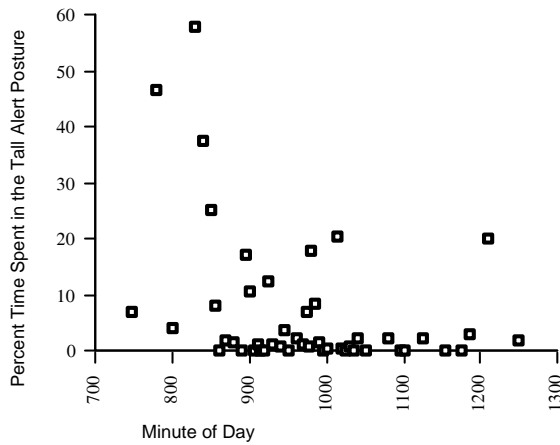
Graph 17 – Effects of Time of Year on the Percent Time Spent in the Alert Investigative Posture. An increase in the alert investigative posture as the year progresses is not significant. $F_{1,34} = 3.94$, $p < 0.06$ for a linear fit; $F_{2,33} = 2.73$, $p < 0.08$ for an exponential fit. Data grouped by day of year.



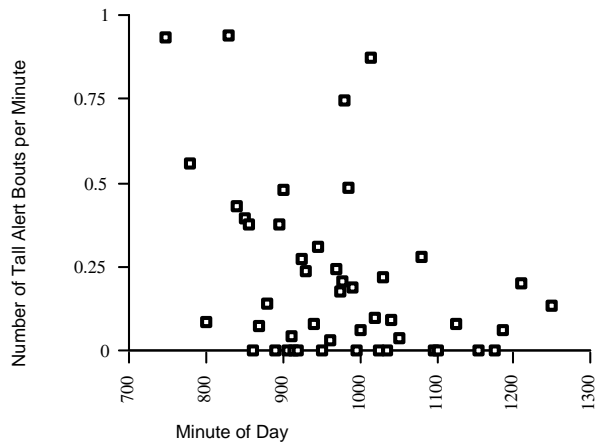
Graph 18 – Effects of Time of Year on the Percent Time Spent in the Tall Alert Posture. A decrease in the tall alert posture over the year is not significant. $F_{1,34} = 1.14$, $p < 0.29$. Data grouped by day of year.



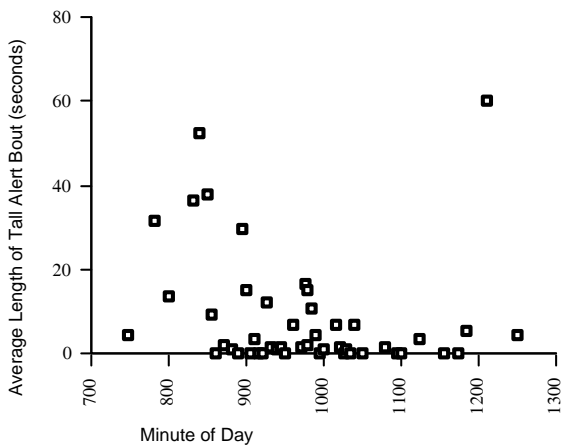
Graph 19 – Effects of Time of Day on the Percent Time Spent in the Alert Investigative Posture. A change in the alert investigative posture over a day is not significant. $F_{1,77} = 0.07$, $p < 0.790$.



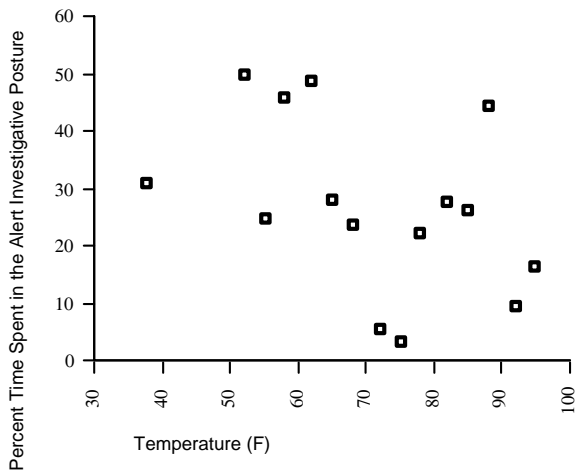
Graph 20 – Effects of Time of Day on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes do change the time spent in the tall alert posture over the course of a day. This is true both for a linear fit ($F_{1,76} = 8.89$, $p < 0.004$, $r^2 = 0.11$) and an exponential fit ($F_{2,75} = 11.18$, $p < 0.01$, $r^2 = 0.23$).



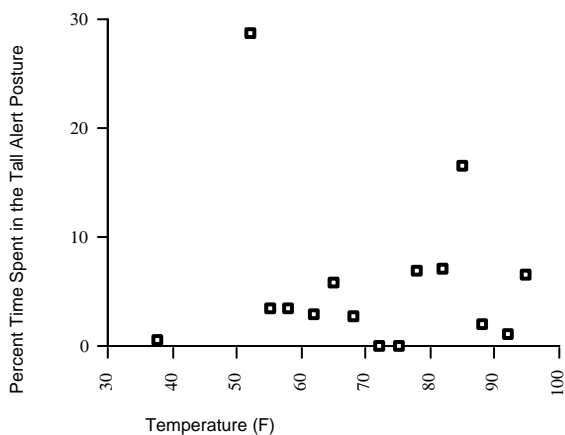
Graph 21 – Effects of Time of Day on the Number of Tall Alert Bouts. Sandhill cranes have fewer tall alert bouts per minute as a day progresses. This is true for both linear ($F_{1,76} = 6.64$, $p < 0.012$, $r^2 = 0.08$) and exponential ($F_{2,75} = 4.57$, $p < 0.013$, $r^2 = 0.11$) trends.



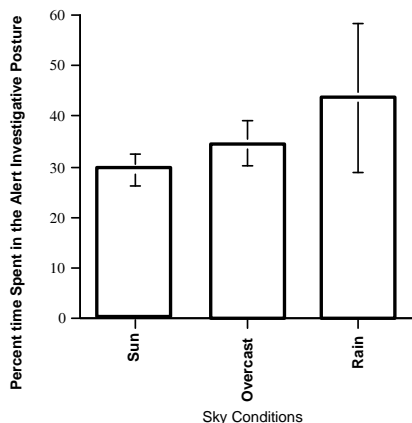
Graph 22 – Effects of Time of Day on the Average Length of Tall Alert Bout. Cranes do not change the length of tall alert bout over the course of a day. $F_{1,76} = 1.84$, $p < 0.179$.



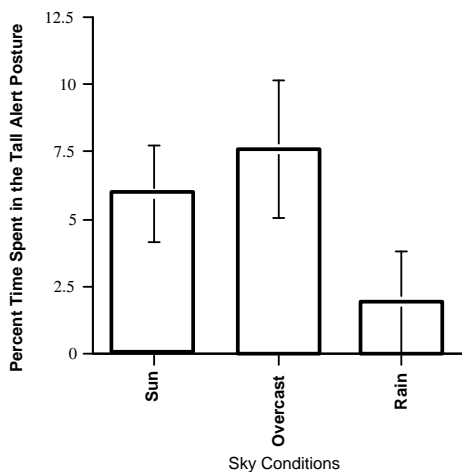
Graph 23 – Effects of Temperature on the Percent Time Spent in the Alert Investigative Posture. Sandhill cranes do not significantly decrease the time spent in the alert investigative posture with increasing temperature. $F_{1,25} = 2.77$, $p < 0.109$. Data grouped by temperature.



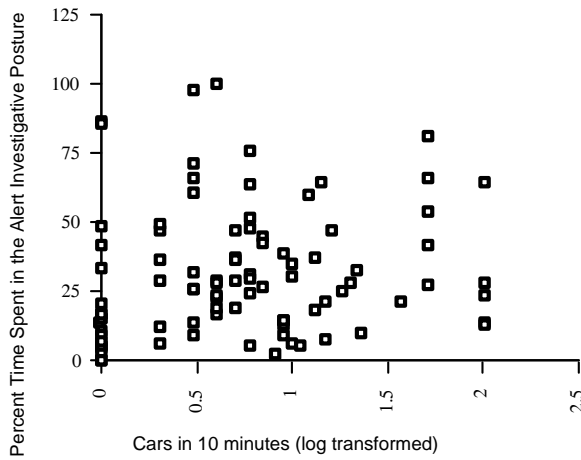
Graph 24 – Effects of Temperature on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes do not significantly decrease the time spent in the tall alert posture with increasing temperature. $F_{1,24} = 0.13$, $p < 0.73$. Data grouped by temperature.



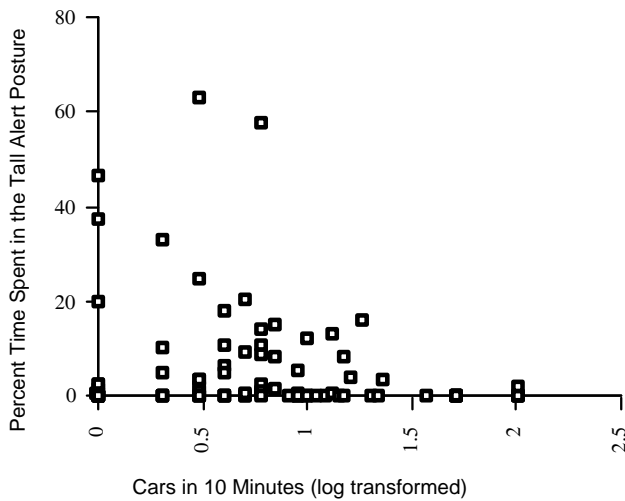
Graph 25 – Effects of Sky Conditions on the Percent Time Spent in the Alert Investigative Posture. Sandhill cranes did not alter the amount of time spent in the alert investigative posture with a change in sky conditions. They spent $29.47 \pm 3.13\%$ of their time in the alert investigative posture under sunny skies. They spent $34.63 \pm 4.52\%$ of their time in the alert investigative posture under cloudy conditions. They spent $43.62 \pm 14.86\%$ of their time in the alert investigative posture under rainy conditions. $H_{44,32,5} = 1.05$, $p < 0.59$, Kruskal-Wallis test.



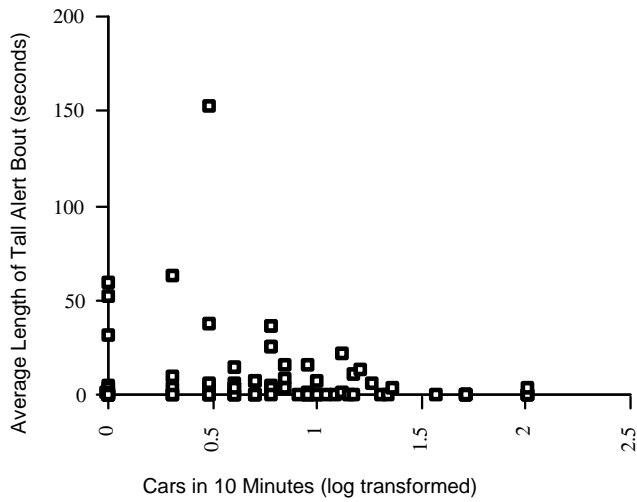
Graph 26 – Effects of Sky Conditions on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes did not alter the amount of time spent in the alert investigative posture with a change in sky conditions. They spent $5.95 \pm 1.79\%$ of their time in the tall alert posture under sunny skies. They spent $7.60 \pm 2.53\%$ of their time in the tall alert posture under cloudy skies. They spent $1.91 \pm 1.91\%$ of their time in the tall alert posture under rainy conditions. $H_{43,32,5} = 1.75$, $p < 0.42$, Kruskal-Wallis test.



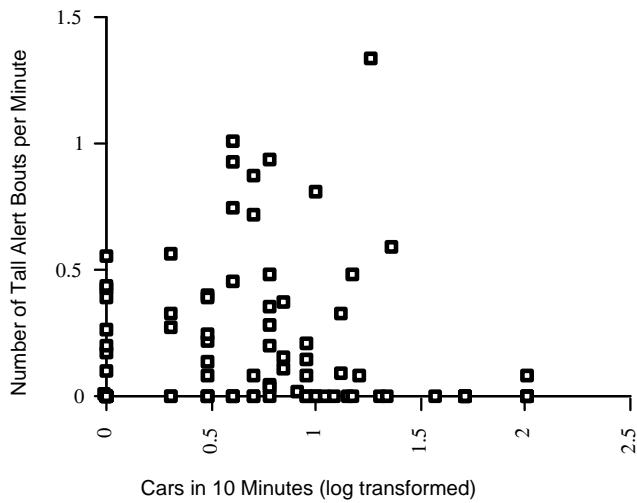
Graph 27 – Effects of Traffic Level on the Percent Time Spent in the Alert Investigative Posture. Cranes do not change the time spent in the alert investigative posture with an increase in traffic levels on the nearest road. $F_{1,68} = 0.06$, $p < 0.814$.



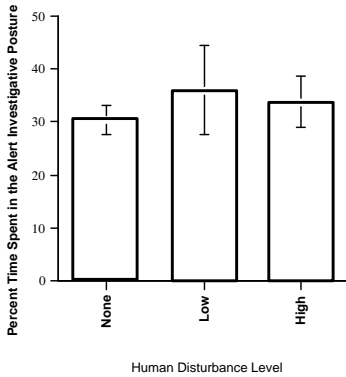
Graph 28 – Effects of Traffic Level on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes decrease the amount of time spent in the tall alert posture with an increase in traffic on the nearest road. $F_{1,67} = 5.50$, $p < 0.022$, $r^2 = 0.08$.



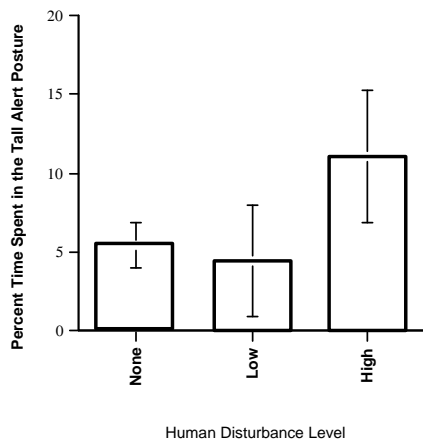
Graph 29 – Effects of Traffic Level on the Average Length of Tall Alert Bout. Sandhill cranes spend less time per tall alert bout as traffic levels increase. $F_{1,67} = 4.81$, $p < 0.032$, $r^2 = 0.07$.



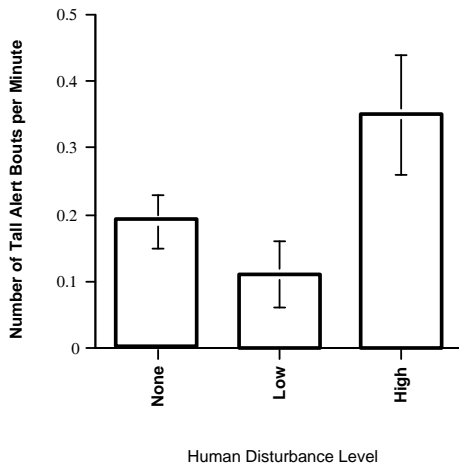
Graph 30 – Effects of Traffic Level on the Number of Tall Alert Bouts. Cranes do not significantly decrease the number of tall alert bouts as traffic levels increase. $F_{1,67} = 3.82$, $p < 0.055$.



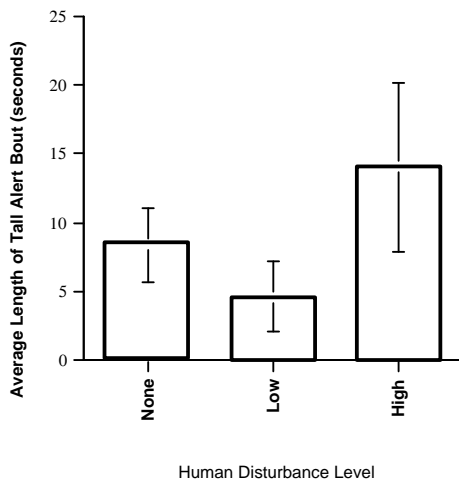
Graph 31 – Effects of Human Disturbance on the Percent Time Spent in the Alert Investigative Posture. Sandhill cranes do not change the amount of time spent in the alert investigative posture with changing human disturbance levels. The mean percent time spent in the alert investigative posture when there is no human disturbance is $30.33 \pm 2.77\%$. The mean percent time spent in the alert investigative posture with moderate human disturbance is $36.02 \pm 8.52\%$. The mean percent time spent in the alert investigative posture with heavy human disturbance is $33.71 \pm 4.82\%$. $H_{68,13,9} = 0.98$, $p < 0.61$, Kruskal-Wallis test.



Graph 32 – Effects of Human Disturbance on the Percent Time Spent in the Tall Alert Posture. Sandhill cranes significantly change the amount of time spent in the tall alert posture with a change in human disturbance. The mean percent time spent in the tall alert posture when there is no human disturbance is $5.38 \pm 1.43\%$. The mean percent time spent in the tall alert posture with moderate human disturbance is $4.43 \pm 3.55\%$. The mean percent time spent in the tall alert posture with heavy human disturbance is $11.06 \pm 4.23\%$. $H_{67,13,9} = 6.50$, $p < 0.04$ Kruskal-Wallis test.



Graph 33 – Effects of Human Disturbance on the Number of Tall Alert Bouts. Sandhill cranes change the number of tall alert bouts in their time budget with a change in human disturbance. The mean number of tall alert bouts per minute with no human disturbance is 0.19 ± 0.04 . The mean number of tall alert bouts per minute with moderate human disturbance is 0.11 ± 0.05 . The mean number of tall alert bouts per minute with heavy human disturbance is 0.35 ± 0.09 . $H_{67,13,9} = 6.56$, $p < 0.04$, Kruskal-Wallis test.



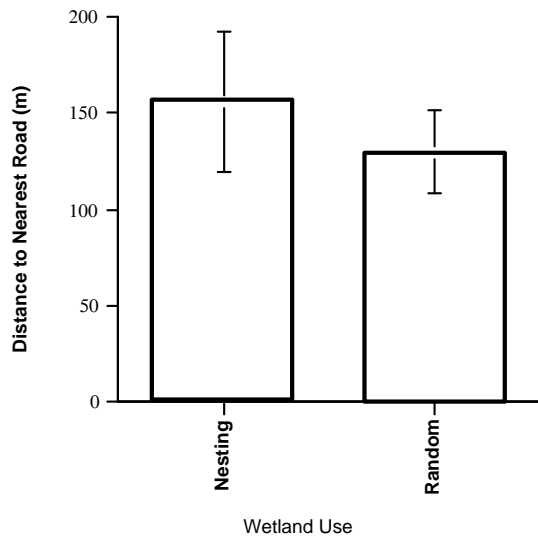
Graph 34 – Effects of Human Disturbance on the Average Length of Tall Alert Bout. Sandhill cranes change the length of time spent in each tall alert bout with a change in human disturbance level. The mean length of tall alert bout with no human disturbance is 8.39 ± 2.70 seconds. The mean length of tall alert bout with moderate human disturbance is 4.62 ± 2.57 seconds. The mean length of tall alert bout with heavy human disturbance is 14.03 ± 6.08 seconds. $H_{67,13,9} = 6.77$, $p < 0.03$ Kruskal-Wallis test.

Category	Emergent	Forested	Open Water and Aquatic Bed	Scrub-Shrub
Observed	38	3	3	5
Expected	18.7	9.6	11.8	9
$\chi^2 = 32.797$				

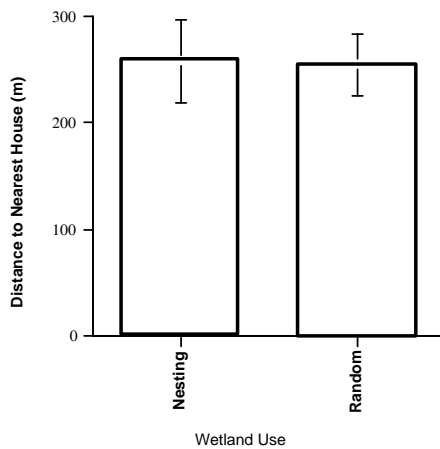
Table 2 – χ^2 table for Nesting Wetland Class. Sandhill cranes selected emergent marshes at a greater frequency than expected but selected forested, open water, and scrub-shrub wetlands less than expected ($p < 0.01$).

Category	Intermittently Exposed	Permanently Flooded	Saturated	Seasonally Flooded	Semipermanently Flooded	Temporarily Flooded
Observed	1	2	8	18	20	0
Expected	4.6	1.7	5.4	22.1	11.9	2
$\chi^2 = 13.596$						

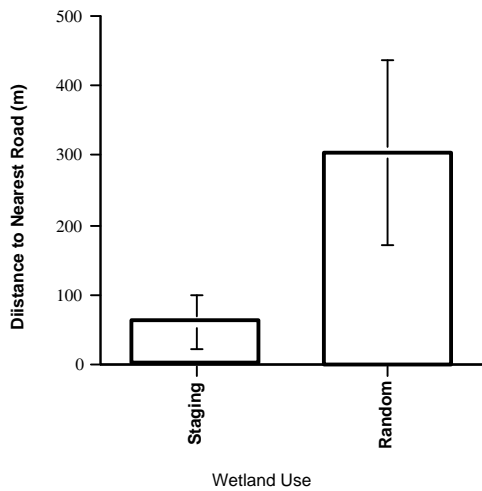
Table 3 – χ^2 table for Nesting Wetland Hydrology. Sandhill cranes selected semi-permanently flooded wetlands at a greater frequency than expected, permanently flooded, saturated and seasonally flooded wetlands in proportion with available wetlands, and intermittently exposed and temporarily flooded wetlands less than expected ($p < 0.03$).



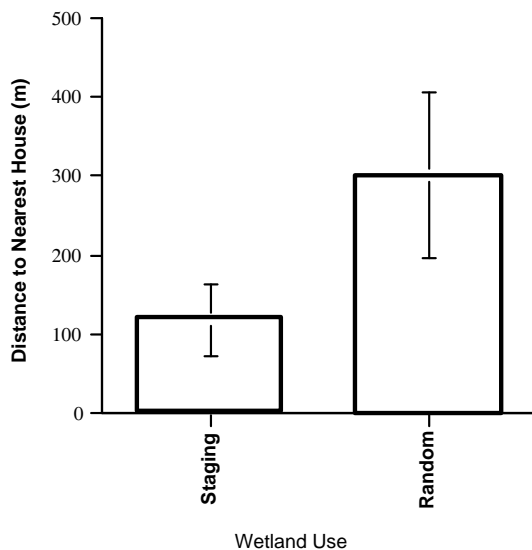
Graph 35 – Nesting Wetland Distance to Nearest Road. Sandhill cranes did not nest significantly farther away from roads than expected. They nested 156.02 ± 36.29 meters from the nearest road. Randomly selected wetlands were 129.469 ± 21.42 meters from the nearest road. $F_{1,96} = 0.40$, $p < 0.53$.



Graph 36 – Nesting Wetland Distance to Nearest House. Sandhill cranes did not nest significantly farther away from houses than expected. The average distance to the nearest house for home range wetlands was 258.02 ± 38.63 m, compared to 255.04 ± 28.89 m for random non-crane wetlands. $F_{1,96} = 0.004$, $p < 0.95$.



Graph 37 – Staging Wetland Distance to the Nearest Road. Sandhill cranes do not use wetlands for staging that are significantly closer to roads than random non-staging wetlands. The average distance to the nearest road for staging wetlands was 60.8 ± 38.20 m while the average distance to the nearest road for random non-staging wetlands was 304.0 ± 133.47 m. $F_{1,10} = 3.07$, $p < 0.11$.



Graph 38 – Staging Wetland Distance to the Nearest House. Sandhill cranes do not use wetlands for staging that are significantly closer to houses than random non-staging wetlands. The average distance to the nearest house for staging wetlands was 117.7 ± 45.44 m, while the distance to the nearest house for random non-staging wetlands was 302 ± 105.01 m. $F_{1,10} = 2.60$, $p < 0.138$.

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