SPATIAL AND TEMPORAL WINTER TERRITORY USE AND BEHAVIORAL

RESPONSES OF WHOOPING CRANES TO HUMAN ACTIVITIES

A Thesis

by

KRISTIN E. LAFEVER

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

August 2006

Major Subject: Wildlife and Fisheries Sciences

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Approved by:

Chair of Committee,   R. Douglas Slack
Committee Members,   Jane Packard
    Fred E. Smeins
Head of Department,   Delbert Gatlin

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ABSTRACT

Spatial and Temporal Winter Territory Use and Behavioral Responses of

Whooping Cranes to Human Activities. (August 2006)

Kristin E. LaFever, B. S., Virginia Polytechnic Institute and State University

Chair of Advisory Committee: Dr. R. Douglas Slack

I investigated spatial and temporal winter behavior and behavioral responses of 5 territorial whooping crane families to human activities at Aransas National Wildlife Refuge during winters 2003-2004 and 2004-2005. Adult and juvenile cranes spent the majority of the day foraging (63% and 66%, respectively). Alert behavior comprised 15% of the cranes' time-activity budgets; preening or resting, and movement each constituted approximately 7% of the time-activity budget. Adults were more alert than juveniles in Jan-Feb. The proportion of time spent in other behaviors did not differ by age.

Over-winter use of territories varied spatially and temporally. Flight occurrence was highest in Nov-Dec, coinciding with establishment of territorial boundaries upon arrival at the wintering grounds. Movement velocity (meters traveled/min) also tended to be highest in Nov-Dec, which may be due to territorial defense and foraging activities. Use of land, open water, and edge habitats (land and water interface) within territories appeared to fluctuate with primary food item availability. Disproportionate use of land habitat by several crane families coincided with peak production of wolfberry (*Lycium carolinianum*) fruit, which occurs in Nov-Dec. Edge habitat was used disproportionately

to its availability throughout the winter, most likely because this habitat type provided refuge for blue crabs (*Callinectes sapidus*), an important food item for whooping cranes. Several families also used open water disproportionately to its availability.

Behavioral responses of whooping cranes to human activities were limited. Responses to varying frequency and intensity of human stimuli were evaluated. Most stimuli did not elicit a response. Two crane families decreased the proportion of time spent foraging during periods of high-intensity stimuli; one family increased movement during such times. Foraging behavior of one family was significantly higher when stimuli frequency was high; alert behavior significantly declined as stimuli frequency increased. The mixed responses of territorial families to varying levels of human stimuli paired with the overall high level of reproductive success of the entire population led to my conclusion that current levels of human activities are not having a detrimental impact on the Aransas-Wood Buffalo whooping crane population.

I dedicate this to my husband, Dave, for his continual

support, motivation, and belief in my abilities.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Doug Slack, for providing support and advice throughout my graduate studies. His discussions about research, conservation, and many other topics have been thought-provoking and have added a great deal to my overall graduate education.

My graduate experience would not have been the same without my fellow graduate students, many of whom helped me with research in the field, as well as with much-appreciated social activities in College Station. For numerous barbeques, Thanksgiving dinners, disc golf games, camping trips and enlightening discussions I would particularly like to thank Rob Powell, Rachel Butzler, Pete Krawczel, Daniel and Stephanie Lee, Tom Dixon, Paige Hill, Meg Byerly, Eddie and Jennie Lyons, Michael Parkes, Anna Munoz and Karlos Sachs, Lance and Eve Fontaine, David and Laura Laurencio, Christa Iacono, Nicole Smolensky, and Reagan Errera. I would also like to thank Kelly Cauthorn for her constant friendship and support. Additionally, I would like to thank several professors who added a great deal to my education: J. Packard, S. Davis, W. Grant, M. J. Peterson, and X. B. Wu. My thesis would never have been completed without the aid of my GIS guru, Amy Snelgrove, or the Statistics Department help desk, particularly Billy Goodner.

I would like to especially acknowledge my husband, Dave, who not only motivated me to begin my graduate degree in the first place, but also helped me every step of the way by providing help in the field, research discussions, a listening ear, as

well as the much-needed foot rubs and social outings. My family has also been very supportive throughout my graduate research, for which I am very thankful.

Finally, I would like to thank the staff and volunteers of the Aransas National Wildlife Refuge, for providing housing, a boat ramp, and other field support, without which this study would have been impossible. And last but not least, I would like to thank the 5 whooping crane families for their excellent behavior, and for sharing both their beautiful and their absurd behaviors with me.

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CHAPTER I

INTRODUCTION

The whooping crane (*Grus americana*), an endangered North American species, currently numbers over 400 individuals in captive and wild populations (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005). The species has slowly increased to its present population level from a low of 15 individuals in 1941 (Miller et al. 1974; Binkley & Miller 1983). In recent years the growth of the population has become nearly exponential (see Binkley & Miller 1988 and Stehn 2004 for growth trends). Captive whooping cranes are maintained at breeding facilities in Wisconsin, Maryland, Florida and Texas, USA, and in Alberta, Canada (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005). Currently there are two "experimental" flocks; one is non-migratory and resides in Florida, the second migrates between Wisconsin and Florida (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005). The experimental flocks are the result of an intensive recovery effort that has been ongoing for several decades (Kuyt 1995; Archibald & Nesbitt 1996). There is only one remaining wild population of whooping cranes, which migrates between breeding grounds in Wood Buffalo National Park, Canada, and wintering grounds on the Texas Gulf coast, in and around the Aransas National Wildlife Refuge (ANWR) (Canadian

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This thesis follows the style of Conservation Biology.

Wildlife Service & U.S. Fish and Wildlife Service 2005). In 2004-2005, there were

215 individuals in this population (Stehn 2005). All captive and experimental whooping

crane flocks originated from the Aransas-Wood Buffalo flock.

Whooping crane ecology

The slow recovery of the whooping crane population may be due, in part, to the

population ecology of the species (Miller et al. 1974). Whooping cranes are

monogamous for life, although re-pairing will occur when one individual of a pair dies

or if newly formed pairs are unsuccessful at raising offspring (Blankinship 1976; Stehn

1992). Two eggs are typically laid during the breeding season, but only one chick

typically survives (Miller 1973; Kuyt 1995). The surviving offspring migrate to the

wintering grounds and spend the winter with the parents before becoming independent at

some point during the migration back to the breeding grounds (Cannon 1996). After

leaving the parents, these "subadults" spend several years in loose flocks composed of

other subadults, before pair formation and breeding attempts begin (Cannon 1996), at

age 3 to 6 years (Stehn & Johnson 1987). Whooping cranes are also long-lived, with the

estimated maximum lifespan of a wild crane being 22-30 years (Lewis 1995). These

factors result in a low growth rate, which is further impacted by mortality due to

predation, abiotic factors, and migration-related deaths (Canadian Wildlife Service &

U.S. Fish and Wildlife Service 2005).

Whooping crane territoriality

Territoriality on wintering grounds is relatively rare among migratory, non-cooperatively breeding birds (Alonso et al. 2004). Whooping crane pairs maintain territories on both the breeding grounds and wintering grounds (Chavez-Ramirez 1996; Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005), which are defended by the resident pair from other adult pairs or subadults (Lewis 1995; Chavez-Ramirez & Slack 1999). Territorial behavior on the wintering grounds results in the available habitat being split by adult pairs. The expansion of the wintering habitat has not been proportional to the increase in the whooping crane population (Chavez-Ramirez 1996). As the crane population has increased, the average size of territories has decreased, due to the tendency of newly-paired birds to establish territories near their parents rather than moving to an unoccupied area of the refuge or a suitable nearby area (Stehn & Johnson 1987). The total area of suitable winter habitat has been listed as potentially the first limiting factor the whooping crane population may encounter as it continues to increase (Binkley & Miller 1983). On Blackjack Peninsula, data from recent studies and annual reports suggest that the area may be saturated in terms of territory numbers (Bonds 2000; Stehn 2005). Since the winter season of 1997-1998, the number of territories found on Blackjack Peninsula has fluctuated between 19 and 22, while the number of territories found in surrounding areas has continued to increase (Bonds 2000; Stehn 2005). Territories located on Blackjack Peninsula are also the smallest, on average, compared to surrounding areas (Bonds 2000).

Whooping crane habitat use within territories was examined by Chavez-Ramirez (1996) who found that crane pairs predominantly utilized the salt marsh habitat type (over bays and uplands), with blue crab (*Callinectes sapidus*) the most commonly consumed food item, followed by wolfberry (*Lycium carolinianum*). Winter territories were described by Bonds (2000) using Geographic Information System (GIS) and remote sensing; however, whooping crane movements spatially and temporally within a territory have not been examined in depth. The behavior of territorial whooping cranes has been broadly examined by Chavez-Ramirez (1996) and Bishop et al. (1985). Chavez-Ramirez (1996) found that foraging within salt marsh habitat was the primary activity, and that foraging location varied throughout the winter season.

Human activity impacts

The impact of human activities on birds has been well studied, particularly on colonial-nesting birds (Burger 1998; Carney & Sydeman 1999; Bolduc & Guillemette 2003). Most studies found that birds responded negatively to high levels of human disturbance (Carney & Sydeman 1999). Studies of human disturbance impacts on wintering birds are less common, mainly due to the difficulty in linking the impacts of disturbance to the population as a whole (Hill et al. 1997). Stillman & Goss-Custard (2002) found that bird response to human disturbance changed as energy requirements increased, due to a decline in food resources. During periods of time when resources were scarce, birds approached a disturbance source more closely, and returned more quickly after a disturbance (Stillman & Goss-Custard 2002). Responses to human

activities may also be dependent on the quality of the occupied site, availability of escape habitat, predation risk at a different site, and the investment made at the occupied site (Gill et al. 2001). Territorial whooping crane pairs may be less inclined to leave an area they actively defend, due to the investment they have made in that area. The number of territories present on Blackjack Peninsula has not changed substantially in 8 years (Bonds 2000; Stehn 2005), which may indicate that there is little suitable marsh habitat available to whooping cranes on Blackjack Peninsula.

Human-related activities are numerous on the Texas coast, often occurring in close proximity to whooping crane territories. Unlike the breeding grounds, where whooping cranes are rarely seen, the ease of viewing cranes on the Texas coast has led to a thriving tourist industry. The tourism industry in nearby coastal towns brings in an estimated $6 million annually, with bird-watchers from all over the country and world traveling to the area to see whooping cranes (Mabie et al. 1989). Tourists mainly view whooping cranes from tour boats that make daily trips along the Blackjack Peninsula, accessing the coastal area by the Gulf Intracoastal Waterway (GIWW). The GIWW borders the eastern shore of Blackjack Peninsula, where the majority of territories on the peninsula are located. The presence of this heavily used shipping channel greatly increases the amount of human activities that occur in close proximity to whooping crane territories. Barges, recreational vessels, and commercial boats are commonly seen traveling along the GIWW (personal observation).

Evaluation of human disturbance effects on wintering whooping cranes has been listed as an important research need (U.S. Fish and Wildlife Service 1994). Human

activities in close proximity to wintering territories could potentially affect whooping cranes by increasing the amount of time spent alert, which could decrease the amount of time spent foraging. Human activities may also drive cranes away from preferred foraging areas, thereby decreasing the quality and quantity of food obtained. In my study, I will determine the behavioral response of cranes to localized human activities. The patterns of human activities during the winter months as well as the behavioral response by territorial crane pairs is important in assessing the potential impact of human presence on the over-winter success of whooping cranes.

Objectives

I evaluated habitat use and behavior patterns of whooping cranes wintering at ANWR for two primary purposes. The first purpose is to provide baseline data on territorial crane wintering behavior. These data will be increasingly important as the crane population continues to grow, and will allow for future comparisons of behavior, territory size, and effect of human activities. The second purpose is to understand the utilization of territories spatially and temporally on Blackjack Peninsula, where the smallest whooping crane territories occur (Bonds 2000). These data would provide information that could be used in the estimation of minimum territory size of whooping cranes and habitat saturation.

My specific objectives for this study were:

1. Develop a time activity budget of whooping cranes wintering on the Blackjack Peninsula of the Aransas National Wildlife Refuge.

2. Determine spatial and temporal habitat use by whooping crane family groups on winter territories.

3. Determine relationship of changes in behavior to human activities on wintering grounds.

Study site

ANWR is located on the Texas coast in Aransas and Refugio counties, approximately 60 km north of Corpus Christi, TX. The refuge is primarily located on Blackjack Peninsula, and covers over 28,330 hectares. Whooping crane wintering territories were located along the edge of Blackjack Peninsula, where salt marsh habitat made up the majority of each territory, and was the primary foraging area (Chavez-Ramirez 1996). The vegetation community of the salt marsh consisted mainly of smooth cordgrass (*Spartina alterniflora*), glasswort (*Salicornia virginiana*), saltwort (*Batis maritima*), sea-oxeye daisy (*Borrichia frutescens*), wolfberry (*Lycium carolinianum*), saltgrass (*Distichlis spicata*), and shoregrass (*Monanthochloe littoralis*) (Stutzenbaker 1999). Upland habitats adjacent to the salt marsh were dominated by marshhay cordgrass (*Spartina patens*) in the grasslands, and scrub live oak (*Quercus virginiana*) (Chavez-Ramirez 1996).

The five whooping crane territories that were observed ranged from the northern end to the southern tip of Blackjack Peninsula, in Aransas County. All territories were adjacent to the GIWW or adjacent to a bay located on the GIWW (Figure 1). Territories were primarily composed of salt-marsh habitat, which can be described as a mosaic of marsh vegetation and intermittently inundated ponds. Inundation and salinity of ponds varied throughout the year, depending on tidal cycles, precipitation and freshwater inflows from the Guadalupe and San Antonio rivers located north of Blackjack Peninsula. Observations were conducted from December through April of 2003-2004 and October through April of 2004-2005.
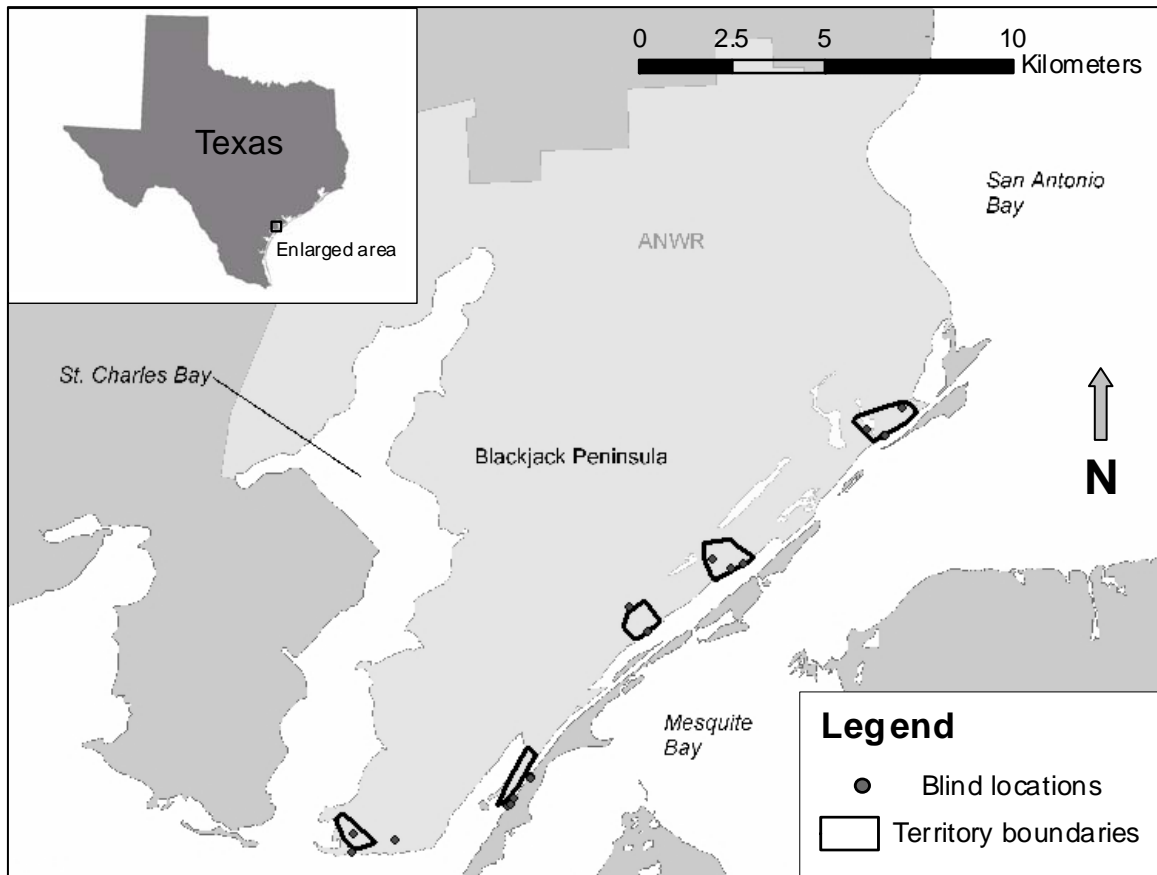
Figure 1. Map of study area, located on the Blackjack Peninsula, in Aransas County, Texas. Five whooping crane territories from north to south are Boat Ramp, Pump Canal, Pipeline, Lobstick, and Blackjack.

CHAPTER II

WINTERING BEHAVIOR OF TERRITORIAL CRANES

Introduction

In order to understand optimal use of time by an animal, the division of effort among behavioral activities must be known (Wolf & Hainsworth 1971). Time spent foraging is generally considered the most important activity; however, adequate time must also be contributed to anti-predator vigilance, reproduction, and self-maintenance (Armitage et al. 1996). Wintering animals do not have to dedicate time to reproduction, although they may support offspring for a portion of the non-breeding season. Wintering time budgets of birds vary, depending on species, environmental conditions, and food availability (Verbeek 1972). Optimal time budgets were proposed by Verner (1965), as a way of explaining the time budgets adopted by birds in relation to various environmental conditions.

Behavior of whooping cranes on the wintering grounds on the Texas Gulf coast has been studied by several researchers; however, few of these studies have examined in detail the over-winter behavior of territorial whooping crane pairs (Bishop et al. 1985; Chavez-Ramirez 1996; Chavez-Ramirez et al. 1996). Previous studies have focused on subadult whooping crane behavior (Bishop et al. 1985), use of fire-treated upland areas where whooping cranes aggregate to forage on acorns and other items (Chavez-Ramirez et al. 1996), or on foraging habitat preferences within the wintering grounds (Chavez-

Ramirez 1996). Territorial crane pairs make up the majority of the whooping crane population, and their winter behavior can provide insights into the amount of energy devoted to territorial defense, at the expense of foraging effort and other activities. Territoriality on the wintering grounds of a migrant species is hypothesized to occur as a food acquisition strategy, or an anti-predator strategy (Alonso et al. 2004). On the wintering grounds, whooping cranes have few known predators; however, coyotes (*Canis latrans*), bobcats (*Felis rufus*), and great-horned owls (*Bubo virginianus*) pose a threat in particular to young or injured cranes (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005). Mortality on the wintering grounds constitutes a small fraction of overall crane mortality (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005), suggesting that territories are maintained in order to secure food resources for the winter season.

Approximately one-third of the wild population of whooping cranes winters on the Blackjack Peninsula of ANWR, Texas, while the remainder winters in the surrounding area, primarily on several barrier islands (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005). Territories located on Blackjack Peninsula are, on average, the smallest whooping crane winter territories on the Texas coast (Bonds 2000), and the number of territories located on the Peninsula has not changed substantially in 8 winters (Stehn 2005). These 2 factors may indicate that Blackjack Peninsula is saturated with whooping crane territories. The behaviors exhibited by territorial cranes on this portion of their wintering range may provide beneficial information as the remainder of the winter grounds become saturated with territorial birds.

The objective of this study was to develop a time-activity budget for territorial cranes on Blackjack Peninsula, and to investigate how adult and juvenile crane behavior varies throughout the winter season. Based on previous studies of wintering-bird time budgets, I hypothesized that foraging is the primary activity of territorial cranes.

Methods

I observed behavior of 5 crane families on Blackjack Peninsula identified from north to south as Boat Ramp (BR), Pump Canal (PC), Pipeline (PL), Lobstick (LS) and Blackjack (BJ) (Figure 1). Observations occurred during daylight hours, from sunrise to sunset, in different periods of the day: early morning, late morning, early afternoon, and late afternoon. The exact duration of the observation periods varied slightly due to changing day length, but the periods were approximately 2.5 hours in length. Data were collected using 10X binoculars and a 20-60X spotting scope. Territory location and period were randomly selected each day, with the provision that the same territory was not observed more than one period per day; i.e., if one territory was observed in the afternoon, a minimum of one night passed before it was observed again.

An instantaneous scan sampling technique was used for each adult pair or family (Altmann 1974). During each observation period, cranes were observed for a 30-min session, with a minimum 10-min break between sessions. All members of a resident pair or family of cranes were observed concurrently. During each 30-min session, a scan of the pair or family of cranes was conducted every 30 seconds, and instantaneous behavior was recorded for each crane. Behaviors were categorized into the following activities:

foraging; searching; flying; alert; locomotion; preen or maintenance; rest or loaf; agonistic; vocalization; courtship; and unknown (Table 1). In order to account for all behaviors that might occur, vocalization and courtship were included; however, these are behavioral events, typically lasting less than 10 seconds. It is highly unlikely that a behavioral event, which is instantaneous or of short duration, will occur at the exact instant as the sampling point. For this reason, instantaneous sampling is not recommended if behavioral events are the focus of the research (Lehner 1996). In this study, behavioral states (such as foraging, alert, preening, etc.) were of primary interest, and therefore instantaneous sampling was appropriate. Instantaneous sampling is a common method used to formulate time budgets (Lehner 1996).

In total, I conducted 276 hours of observation at the 5 territories. In winter 2003-2004, 2 territorial pairs had juveniles: PL had one juvenile, while LS had two juveniles. In winter 2004-2005, BR, PC, and LS pairs all had one juvenile. The pair in the BJ territory was the only pair that did not have a juvenile either winter. Data were not collected at BJ territory during winter 2004-2005, because the area was not maintained as a territory by a pair of cranes.

Table 1: Definitions of behavioral activities.

Behavior Category	Definition
Forage	Actively foraging - includes eating, handling prey, probing for prey (includes behaviors under Foraging and Swallowing categories as defined by Ellis et al. (1991)).
Search	Walking slowly with head lowered looking for food - not actively probing or handling prey
Flight	Includes pre-flight posture and active flight (flight and transitional action patterns behaviors defined by Ellis et al. (1991)).
Alert	Standing up straight with head at 90 degree angle to neck
Agonistic	Showing aggressive behavior in various different ways, such as displaying red head-patch, jump-raking, walking directly at intruder while alarm calling (agonistic behaviors defined by Ellis et al. (1998).
Preening	Preening feathers - includes stretching, bathing, and other maintenance behaviors defined by Ellis et al. (1991).
Locomotion	Non-flight movement not associated with foraging - head up, walking or running, according to ambulatory definition by Ellis et al. (1991).
Vocalization	Any type of vocalization - includes alarm calls, unison calls, contact calls, pre-flight calls (Ellis et al. 1998).
Rest or Loaf	Standing with head tucked onto back, or standing still with head tilted down onto neck, sometimes with one leg tucked up into feathers. Includes behaviors Head-droop-sleep, Head-tuck-sleep, and Head-tuck-watch defined by Ellis et al. (1991).
Courtship	Includes dancing and other courtship displays defined by Ellis et al. (1998).
Unknown	Occurred when crane was out of sight behind upland or tall vegetation.

Data analysis

Time-budget data were analyzed using SAS 9.0. Four main behavioral categories were evaluated (see Table 1 for definitions of behavioral activities): Foraging (includes forage and search), Alert, Comfort (includes preening and resting), and Movement (includes flight and ambulatory locomotion). The winter season was broken into three temporal periods: November-December (Nov-Dec), January-February (Jan-Feb), and March-April (Mar-Apr), and will be referred to as the "month category". Frequency data were grouped for analysis by age (adult or juvenile), period of day (early morning, late morning, early afternoon and late afternoon) and month category. Behavioral data are typically presented as proportion or percentage of time spent in activities (Galicia & Baldassarre 1997). I converted behavior frequencies in a 30-min session to proportion of time by calculating the number of records for each activity in the 30-min session out of the total number of records in that session (Cucco & Malacarne 1997; Galicia & Baldassarre 1997; Mace 2000; Bright et al. 2003). This resulted in a single proportion value of each behavior for each observation session. Proportions were transformed using an arcsine square root transformation, commonly used for proportion data (Dytham 2003). The transformed proportions for each behavior were averaged within each combination of month category and period of day for each age group, and statistical comparisons were performed with these average values using analysis-of-variance (ANOVA), rejecting the null hypothesis at $p < 0.05$ (Galicia & Baldassarre 1997). A mixed effects model was used, which included a "random effect" for territory, in order to account for the correlation among behaviors from the same territory. If a

significant effect was detected, a contrast function was performed in SAS to determine

where differences were in the factor groups (month category and period of day).

Results

Adult and juvenile whooping cranes spent the greatest proportion of time

foraging and searching for food (average = 0.65) (Tables 2 and 3). Alert behavior was

the second-most common behavior (adults = 0.16, juvenile = 0.14), followed by

preening (adult = 0.06, juvenile = 0.05) and locomotion (adult = 0.07, juvenile = 0.06).

Agonistic, vocalization, and courtship behaviors were rarely seen, and were not included

in further analyses. Proportion of time spent in the four main behavioral categories did

not differ by age, with the exception of alert behavior. Adults were more alert than

juveniles during Jan-Feb (p = 0.003); no other differences in adult and juvenile behavior

were found (Table 4).

Results of day period and month category comparison

Adult foraging, alert and comfort behaviors were not found to be dependent on

the period of day or month category (Table 5). The proportion of time spent in

movement varied significantly between month categories (p=0.012) (Table 5), but not

between periods of the day. Movement in Nov-Dec was significantly higher than Jan-

Feb (p=0.004), and slightly higher than movement in Mar-Apr (p=0.063) (Figure 2).

The interaction of month category and period of day was also found to be significant for

Table 2. Mean proportion of time spent in each activity by adult whooping cranes on 5 territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. n = number of 30-min observation sessions.

	BR	PC	PL	LS	BJ	Average
	n=243	n=242	n=236	n=201	n=76	
Forage	.430	.486	.539	.499	.339	.458
Search	.198	.192	.160	.163	.251	.193
Flight	.005	.010	.003	.003	.009	.006
Alert	.163	.162	.139	.166	.191	.164
Agonistic	.000	.007	.009	.000	.004	.004
Preening	.073	.023	.047	.069	.083	.059
Locomotion	.074	.078	.053	.045	.087	.067
Vocalization	.001	.003	.001	.001	.001	.001
Rest/Loaf	.033	.005	.003	.005	.006	.010
Courtship	.000	.000	.000	.000	.000	.000
Unknown	.024	.035	.047	.049	.031	.037

Table 3. Mean proportion of time spent in each activity by juvenile whooping cranes on 4 territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. n = number of 30-min observation sessions.

	BR	PC	PL	LS	Average
	n=81	n=83	n=19	N=90	
Forage	0.538	0.595	0.308	0.525	0.492
Search	0.126	0.178	0.170	0.152	0.157
Flight	0.004	0.011	0.004	0.001	0.005
Alert	0.168	0.111	0.150	0.126	0.139
Agonistic	0.000	0.000	0.000	0.000	0.000
Preening	0.064	0.023	0.080	0.050	0.054
Locomotion	0.066	0.060	0.087	0.046	0.065
Rest/Loaf	0.017	0.005	0.019	0.037	0.020
Unknown	0.017	0.017	0.182	0.063	0.070

Table 4. Mean proportion of time spent in four main behaviors by
territorial whooping cranes during winter 2003-2004 and 2004-2005 at
ANWR, Texas, USA. n = number of 30-min observation sessions.

	Nov-Dec		Jan-Feb		Mar-Apr	
	Adults n= 248	Juvenile n=79	Adults n= 374	Juvenile n= 114	Adults n= 376	Juvenile n= 80
Foraging	0.6093	0.6824	0.6672	0.6652	0.6583	0.6626
Alert	0.1872	0.1532	0.1649	0.1240	0.1519	0.1565
Comfort	0.0597	0.0534	0.0604	0.0822	0.0684	0.0661
Movement	0.0991	0.0830	0.0495	0.0574	0.0858	0.0703

Table 5. Results of ANOVA test for differences in proportion of time spent in each activity between period of day and month category. ** indicates statistical significance of p < 0.05.

	Adults							
	Foraging		Alert		Comfort		Movement	
	F value	p-value	F value	p-value	F value	p-value	F value	p-value
Period of day	0.61	0.620	0.68	0.581	0.95	0.445	0.26	0.851
Month category	1.09	0.380	1.12	0.373	0.85	0.462	8.12	0.012**
Interaction (period*month)	0.32	0.918	0.39	0.875	2.69	0.046**	2.47	0.061

	Juveniles							
	Foraging		Alert		Comfort		Movement	
	F value	p-value	F value	p-value	F value	p-value	F value	p-value
Period of day	0.74	0.557	0.42	0.746	1.00	0.442	0.39	0.765
Month category	0.11	0.898	0.02	0.980	0.51	0.63	0.24	0.797
Interaction (period*month)	0.89	0.534	0.90	0.525	2.69	0.069	2.31	0.103
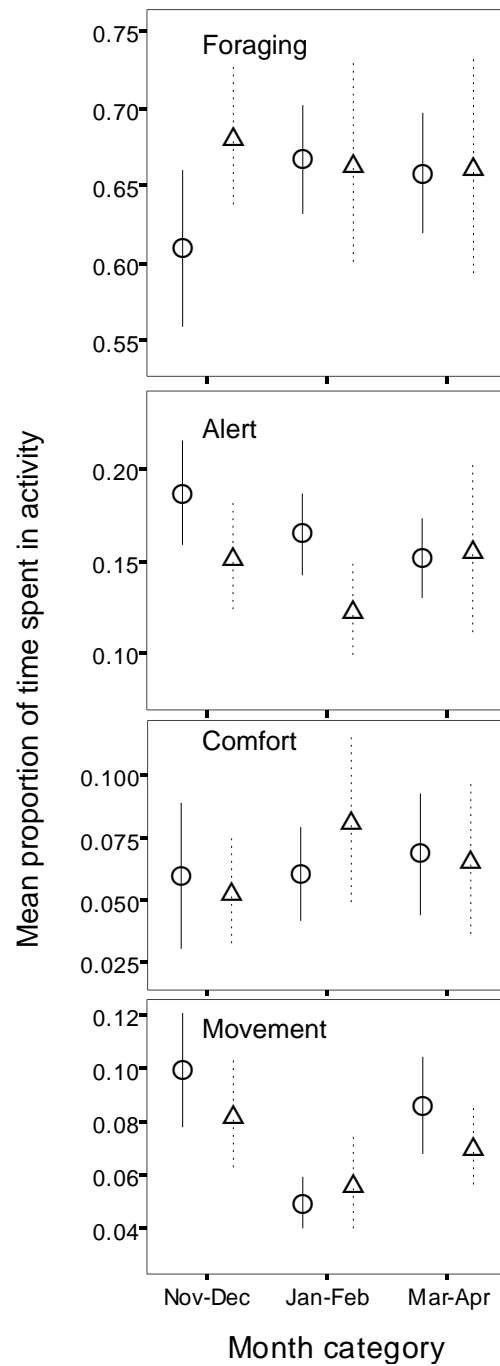
Figure 2. Variation in mean proportion of time spent in 4 main activities within month category by adult (open circles) and juvenile (triangles) whooping cranes during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. Vertical lines represent 95% confidence intervals.

adult comfort behaviors (p = 0.046), primarily due to several periods of day and month categories when no comfort behavior occurred, as well as a significantly higher proportion of time spent in comfort during early afternoon in Jan-Feb (p < 0.0001). Juvenile behavior was not dependent on the period of day or month category for any behavior category (Table 5).

Movement was a combination of flight and locomotion. When separated into these categories, both flight and locomotion were greatest in early winter (Figure 3). Time spent in flight in Nov-Dec was more than double that in Jan-Feb and Mar-Apr, however, it never constituted more than 1% of the overall time budget of the whooping cranes. In total, 114 flight events were observed during winter 2003-2004 and 2004-2005. Over half of these flights were made for unknown reasons (Table 6). 29% of the flight events were made for territorial defense, which occurred most commonly in Nov-Dec. Flight was also seen in response to upland burning, where cranes went to forage, and in response to human stimuli.
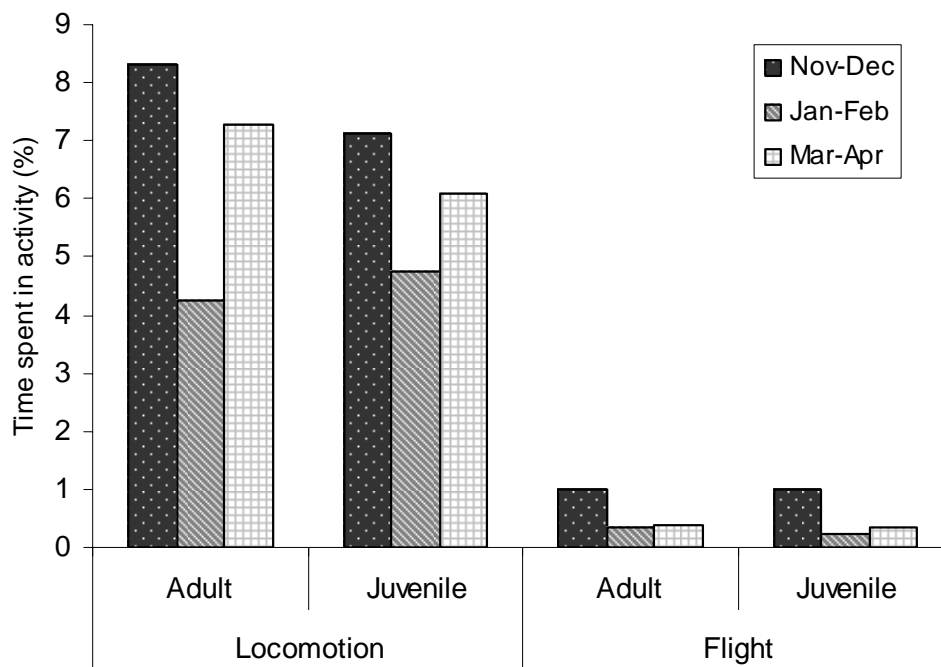
Figure 3. Percent time spent in locomotion and flight by territorial whooping crane families throughout winter 2003-2004 and 2004-2005 at ANWR, Texas, USA.

Table 6. Cause of flight events that occurred in winter 2003-2004 and 2004-2005 at 5 whooping crane winter territories at ANWR, Texas, USA.

Reason	Frequency	Percent
Territorial defense	33	28.9
Flew to burn	5	4.4
Human stimuli	8	7.0
Unknown	68	59.6
Total	114	100.0

Discussion

Foraging is one of the most important behaviors of birds (Gibson 1978), and typically represents a higher proportion of time-activity budgets during the winter season, when little energy is being used for reproductive efforts. Whooping cranes are no exception – the average proportion of time spent foraging was above 0.60 throughout the entire winter for both adults and juveniles. Juvenile foraging behavior consistently averaged approximately 0.69 throughout the winter. Although adult foraging behavior did not show statistically significant variation due to month category, there appeared to be a slightly lower amount of time spent foraging in Nov-Dec, when alert and movement behaviors were higher, which may be related to greater emphasis on territory exploration and defense. The higher proportion of flight behavior also indicates that territorial defense was greater in Nov-Dec, as the majority of flights made were to chase other whooping cranes away from the vicinity. This period of territory defense occurred primarily within the first month of the territorial pair's arrival on the wintering grounds. After this time, neighboring territorial pairs rarely ranged into each other's territories, and subadults were seldom seen within a territory.

Agonistic encounters with other cranes rarely occurred. Alonso et al. (2004) found that territorial common cranes (*Grus grus*) spend a greater amount of time vigilant, but that the juvenile of the territorial pair was never involved in an aggressive encounter, unlike juveniles that were part of a flock. Despite the cost of remaining vigilant, reduction of aggressive encounters directed towards juveniles implied an added benefit for crane pairs that maintained a winter territory (Alonso et al. 2004). The

instantaneous intake rate (grams/min feeding) of territorial common cranes was higher

than that of cranes in a flock, so that despite the lower percentage of time spent foraging

by territorial cranes, the gross daily intake of food was roughly the same (Alonso et al.

2004). The higher intake rate compensated for the increased time spent in vigilance by

territorial cranes (Alonso et al. 2004). Agonistic behavior constituted, on average,

0.38% of the time budget of adult whooping cranes on Blackjack Peninsula.

Vocalizations, in particular guard calls and alarm calls, could also be used as a way to

maintain a territory. Vocalizations of all types made up less than 0.25% of the overall

time budget of adult cranes; however, the instantaneous sampling method may have

resulted in event behaviors, such as vocalizations, being underrepresented in the time

budget (Lehner 1996). Flying was most often associated with territorial defense, and

was therefore related to agonistic encounters. The percentage of time spent in flight was

less than 1% at any time during the winter. Based on these results, agonistic encounters

appear to be a rare event, meaning they constitute a very small role in the time-budget of

whooping cranes. Flight requires the greatest amount of energy of all whooping crane

behaviors (Chavez-Ramirez 1996), which indicates that agonistic events involving flight

are a costly activity in terms of required energy. Territorial defense and agonistic

encounters contribute to reduced available time that could be spent foraging, which

could be important early in the winter, after cranes have just completed the migration

from Canada.

Proportion of time spent alert was greatest in Nov-Dec, which could be explained

by increased vigilance upon arrival on the wintering grounds, similar to the findings of

Alonso et al. (2004) with common cranes. The higher level of alert behavior was not statistically significant when compared to Jan-Feb and Mar-Apr, which could be explained by other factors, such as increased protection of a young juvenile or anti-predator vigilance.

The wintering behavior of territorial whooping cranes on the Texas coast is similar to other crane species, such as common cranes (Alonso & Alonso 1992) and hooded cranes (*Grus monacha*) (Eguchi et al. 1991). Alonso & Alonso (1992) found that, on average, wintering common cranes spent 62% of the time foraging and showed similar daily variations in foraging and alert behavior, as foraging behavior decreased in the middle portions of the day, while alert behavior increased slightly. Eguchi et al. (1991) reported foraging by wintering hooded cranes to be approximately 58% of the time budget. Foraging was considered an all-day activity by Siberian cranes (*Grus leucogeranus*) (Vuosalo-Tavakoli 1991) and grey crowned cranes (*Balearica regulorum*) (Gichuki & Gichuki 1991). Of the crane species mentioned, all exhibit territoriality on wintering grounds to some degree, except for grey crowned cranes (Alonso et al. 2004). Common cranes have been found to maintain winter territories some years, particularly if a bonded pair has a juvenile, but is less likely to maintain a territory if no juvenile is present (Alonso et al. 2004).

Differences between adult and juvenile behavior were not significant for the most part, however, there were several consistent patterns. Juveniles spent slightly more time foraging, while the adults tended to be more alert. In Jan-Feb, adults were found to be significantly more alert than juveniles. The reason for this change is unknown.

Juveniles spent slightly less time in movement overall. During territorial encounters,

one adult would often fly after intruders to chase them away, leaving the other adult with

the juvenile, which may account for the minor variation in the proportion of time spent

in movement.

CHAPTER III

SPATIAL AND TEMPORAL USE OF TERRITORIES

Introduction

Spatial analysis of whooping crane wintering territories and the way in which whooping cranes move about their territories has not been fully investigated. Chavez-Ramirez & Slack (1999) found that reduced food availability in salt marsh habitat might have resulted in territorial pairs spending more time away from their territories. Within territories, Chavez-Ramirez (1996) found that whooping cranes spent the majority of time in salt marsh habitats, as opposed to time spent in uplands and open bays. Use of mesohabitats, such as lakes, ponds, and pools within the salt marsh varied by month and location (Chavez-Ramirez 1996). Whooping cranes currently maintain territories in several areas of the Texas Gulf Coast: Blackjack Peninsula (constitutes majority of ANWR area), Matagorda Island, San Jose Island, Welder Flats, and the Lamar Tract. Of these areas, Blackjack Peninsula has the smallest average territory size, approximately 63 ha (Bonds 2000). Territory sizes in the surrounding areas range from 200-300 ha (Bonds 2000). The number of territories in these surrounding areas has been increasing, and the average size is decreasing (Stehn 2004). After this population of cranes recovered from a low of 15 individuals in 1941 (Canadian Wildlife Service & U.S. Fish and Wildlife Service 2005), all whooping cranes wintered on Blackjack Peninsula. As the population grew, the wintering range slowly expanded to the surrounding areas. The number of territories on Blackjack Peninsula grew, apportioning the available marsh

habitat until 1998. Since 1998, the number of territories located on Blackjack Peninsula has remained essentially the same (Stehn 2005), indicating that this area may have reached saturation. Hence, the territories located in this area provide important information about the minimum area required and the habitat components necessary for wintering cranes.

Permanent ponds are scattered throughout the territories, and provide important habitat for a primary food item of the whooping crane, the blue crab (*Callinectes sapidus*) (Chavez-Ramirez 1996). Between 62%-97% of the cranes wintering diet is comprised of blue crabs; the remaining dietary items are primarily wolfberry fruits, clams, and to a lesser degree, snails, reptiles, insects, and vegetation (Chavez-Ramirez 1996). Blue crabs are found in ponds and during the winter months are more numerous along the pond edge, when vegetative cover is absent from pond bottoms (D. Rutka, pers. comm.). Blue crabs appear to be most abundant within the salt marsh habitat during early winter and spring, and the least available during mid-winter (D. Rutka, pers. comm.) The peak of wolfberry fruit production is during October and November; at other times of the year, berries are rarely found (Chavez-Ramirez 1996; Butzler 2006).

Within-territory habitat selection could provide valuable insights on the use of foraging habitat, particularly as food availability changes throughout the winter season. The objective of this study is to determine spatial and temporal habitat use by whooping crane family groups on winter territories. According to optimal foraging theory, I expect increased movement to occur when the variety and abundance of acceptable food items is reduced (MacArthur & Pianka 1966). Based on known food availability patterns, I

hypothesized that food availability would be lowest in mid-winter (January and February), and as a result, movement within the territory would increase during this time, as cranes were forced to spend greater amounts of time searching for food. During the peak of wolfberry fruit production, I hypothesized that cranes would spend more time in vegetated areas of their territories than in open water, due to the ease of capture and the short duration of availability of the berries. I also hypothesized that territorial disputes between neighboring cranes or between territorial cranes and subadults would result in greater movement velocities and higher number of flights in early winter (Nov-Dec), when cranes are arriving on the wintering grounds and re-establishing territories.

Pitelka (1959) defined territory as "an exclusive area" used by an animal. This definition does not rely solely on the occurrence of defensive behavior, making it useful for the delineation of territories occupied by animals that do not often have aggressive territorial encounters. Aggressive encounters are rare in the behavioral repertoire of whooping cranes (see Chapter II), making exact locations of defense difficult to determine. While adult pairs of cranes actively defend their territories, disputes with other cranes are rarely seen, and often when they do occur, the exact boundary is not clear (for example, when a crane flies after intruders, and does not land at the "border"). Vocalizations between neighboring cranes are common, and could be a method of alerting neighbors to their presence and thereby avoiding a territorial dispute. For these purposes, the term "territory" will refer to the area of marsh habitat that is used by one family of cranes throughout the winter season.

Methods

Crane families were observed from blinds on the Blackjack Peninsula. Observations occurred during daylight hours, from sunrise to sunset, in different periods of the day: early morning, late morning, early afternoon, and late afternoon. The length of each period of day was determined by dividing the daylight hours into 4 equal periods. As the day length changed over the course of the winter, so did the length of each period of day. On average, each period of day was 2.5 hours. Territory and day period were randomly selected for observation. Whooping crane spatial locations were collected concurrently with behavioral data. Observation sessions lasted 30 min, with a 10-min break between sessions. Several observation sessions were typically conducted within a period. Observed cranes will be referred to as "families" regardless of whether or not a juvenile was present.

During an observation session, the distance to the focal birds was recorded using a Bushnell Yardage Pro 800 Rangefinder, and the bearing recorded using a compass. One location point was collected every 5 min for each crane present. If the family flew to a new location, a new location point was taken immediately after landing, regardless of when the previous location point was collected. Distance and bearing data were transferred to a map from the blind location using ArcView 3.3 and ArcMap 9.0. Movement paths during the 30-min session were created for each crane using ArcMap 9.0. A 5-m buffer was created around each path to account for microscale movements that were not detected, as well as to account for the precision-limitations of the measurement equipment. Movement velocity (i.e., meters traveled/min) was calculated

for each crane in each 30-min session using movement paths. Flight distances for each session were calculated using ArcMap 9.0. Distances flown were averaged for each family for analysis. The percentage of sessions in which flight occurred was calculated for each territory for each month category based on the frequency of flight occurrence.

Using location points, territories were delineated using the Minimum Convex Polygon method for each whooping crane family using the Animal Movements extension (Hooge & Eichenlaub 1997) in ArcView 3.3. Kernel home range (Kernel HR) (95% probability) was also calculated for each crane family, for comparison purposes. For habitat classification of whooping crane territories, GIS coverage data from Bonds (2000) were used to create 3 types of habitat: open water, land and edge. I defined edge habitat as a 5-m-wide piece of habitat that overlays the border between open water and land. Edge habitat provides important escape cover for blue crabs, and may therefore be used preferentially over open water or marsh vegetation (D. Rutka, pers. comm.).

Landscape characteristics of whooping crane territories were evaluated using the computer software FRAGSTATS (McGarigal et al. 2002). The following metrics were calculated for each territory: edge density (m/ha), largest patch index (LPI), pond density (number/100ha), landscape shape index (LSI) and clumpiness index (see Appendix A for definitions and calculation of metrics). Landscape metrics (edge density and LSI) measure the aggregate properties of the entire patch mosaic. In this study, each territory was considered one landscape, separate from the others. Class metrics (pond density, LPI, clumpiness index) summarize the metrics for the patches that comprise each class. For this portion of the analysis, two classes were defined: land and water.

Data analysis

Statistical procedures were performed in SPSS version 11.0 (SPSS, Chicago). Flight distance and movement velocity (m/min) for each observation session were calculated and compared between families and month categories using Kruskal-Wallis and Mann-Whitney U tests, rejecting the null hypotheses at $p < 0.05$. Age was not used as a factor, as juveniles and adults traveled together, and were rarely found apart from each other.

To test for habitat selection, the observed number of points in each habitat type was compared to the expected number, which was calculated based on the proportion of each habitat type available within each territory and the number of location points collected within each month category (Lopez et al. 2004). The resulting ratio will be referred to as the selection ratio. Selection ratios < 1 indicates cranes used the habitat type less than expected, while selection ratios > 1 indicate selection (Lopez et al. 2004). In addition to this method, the percentage of each habitat type within the 5-m buffered movement paths was also calculated and compared to the total percentage of each habitat type available within the territory.

Results

Movement velocity and flight distance

Movement velocity varied by family and month category. A comparison of the 5 families within each month category indicated that there was no difference in movement velocity in Nov-Dec (p = 0.303). Movement velocity varied significantly in Jan-Feb and Mar-Apr (p < 0.001); in both cases, BR and LS families had significantly lower movement velocities than PC and PL families (Table 7). When movement velocity was compared within a territory, BR, PC and LS significantly varied over the course of the winter (p ≤ 0.046) (Figure 4). Movement velocity of the BR and LS families was significantly higher in Nov-Dec than Jan-Feb (p= 0.006 and 0.001, respectively). Movement velocity of the PC family gradually increased throughout the winter, resulting in Mar-Apr movement velocity being significantly higher than Nov-Dec (p= .021).

Table 7. Mean movement velocity (meters traveled/min) of each whooping crane family during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. (n = number of 30-min observation sessions).

Family	Nov-Dec			Jan-Feb			Mar-Apr		
	Mean	SD	N	Mean	SD	n	Mean	SD	n
BR	4.77	3.23	19	2.77	1.77	51	3.65	2.28	52
PC	4.83	3.01	31	5.20	3.12	43	6.10	2.77	50
PL	5.10	2.23	34	4.60	2.27	46	5.69	2.78	57
LS	5.35	3.11	36	3.24	1.84	48	4.25	2.78	25
BJ		n/a		3.89	2.45	11	5.02	3.07	19
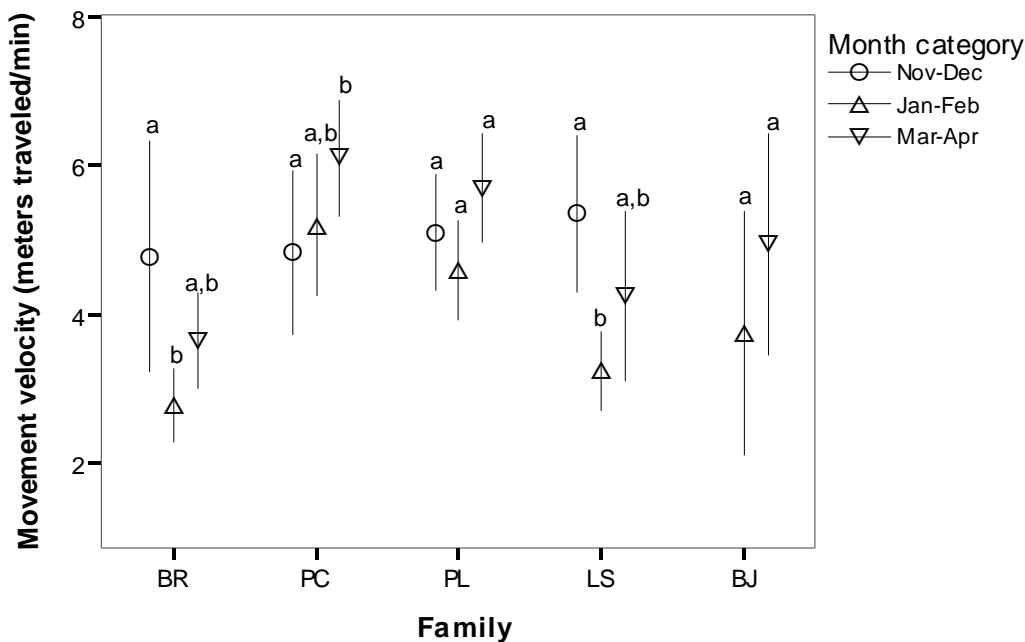
Figure 4. Mean movement velocity (meters traveled/min) of 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. Error bars show the 95% confidence interval. Means with the same letter are not statistically different within family group.

Mean flight distance also varied significantly by family. The mean flight distance used for this analysis was calculated by averaging the distance flown in each session, which includes sessions when no flight occurred (Table 8). In Nov-Dec, flight distance was significantly greater at PC than at BR, PL and LS ($p \leq 0.003$); PL flight distance was significantly greater than that at LS ($p = 0.009$). In Jan-Feb, the BJ family had significantly greater flight distances than the other 4 families ($p \leq 0.001$), and there were no differences by family in Mar-Apr ($p = 0.252$). Within a family, PC, PL and BJ flight distances varied significantly throughout the winter. At PC, flight distance was

greater in Nov-Dec than in Jan-Feb and Mar-Apr ($p \leq 0.001$). Flight distance in Nov-Dec at PL family was greater than Mar-Apr ($p = 0.018$), while at BJ the flight distance was greater in Jan-Feb than in Mar-Apr (0.027).

When the sessions with no flight occurrence were removed from the data, very different results were seen (Table 8). The difference in the average distance flown is due to the frequency of flight throughout the winter. On average, flight occurred during 12% of observation sessions; however, when broken down into families, the percentage of sessions in which flight did occur supports the result that the PC family flew a significantly greater amount in Nov-Dec (Table 9). Although the average distance flown (excluding sessions when no flight occurred) in Nov-Dec at PC was less than that seen at BR (518m and 644m, respectively), flight occurred during 53% of the observation sessions at PC, in comparison to 15% at BR. The BR family flew further distances than the PC family, but much more infrequently. The LS family flew the furthest on average during Jan-Feb and Mar-Apr, and the percentage of sessions in which flight occurred increased, indicating an increase in flight frequency, unlike the remaining families, where flight frequency tended to decrease over the course of the winter.

Table 8. Mean flight distance (m) calculated using all sessions vs. only sessions when flight occurred during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. SD = Standard Deviation of the mean. All sessions n = total number of observation sessions for each family in each month category. Flight only sessions n = number of observation sessions in which a flight event occurred.

Nov-Dec

| | All sessions | | | | Flight only sessions | | |
	Mean distance	SD	n		Mean distance	SD	n
BR	101.54	308.50	19		644.04	576.98	3
PC	322.62	415.01	31		518.40	380.77	17
PL	80.52	179.65	34		293.70	190.16	7
LS	26.69	116.69	36		248.17	130.71	2
BJ	n/a		0		n/a		0

Jan-Feb

| | All sessions | | | | Flight only sessions | | |
	Mean distance	SD	n		Mean distance	SD	n
BR	31.35	90.28	51		235.30	65.51	6
PC	57.08	163.48	43		261.58	153.02	7
PL	12.47	51.49	46		191.18	91.64	3
LS	65.42	260.41	48		1044.89	232.63	3
BJ	164.87	202.33	11		302.26	179.01	6

Mar-Apr

| | All sessions | | | | Flight only sessions | | |
	Mean distance	SD	n		Mean distance	SD	n
BR	30.92	102.82	52		311.28	116.83	5
PC	65.10	201.50	50		261.02	167.14	9
PL	7.94	34.09	57		150.88	14.06	3
LS	173.12	458.10	25		353.78	268.98	5
BJ	28.60	71.80	19		135.85	107.26	4

Table 9. Percentage of sessions in which flight occurred during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. n= total number of observation sessions from territory during month category.

	Nov-Dec		Jan-Feb		Mar-Apr	
	%	n	%	n	%	n
BR	15.79	19	11.77	51	9.62	52
PC	53.13	31	16.28	43	18.00	50
PL	20.59	34	6.52	46	5.26	57
LS	5.56	36	6.25	48	20.00	25
BJ	n/a	0	54.55	11	21.05	19

Habitat selection within territories

Territories ranged in size from 44 to 108 ha, with LS being the smallest, and PC the largest (Figure 5). The total area and percentage of each habitat type varied within each territory (Figure 6). Land habitat comprised the majority of PC and BJ territories, while PL and LS territories were nearly evenly split into the three habitat types. Pipeline had the highest percentage of edge habitat, followed by LS. Boat Ramp and Pipeline territories had the highest percentage of open water.

Habitat selection varied both between territory and month category (Table 10). In general, edge habitat was most selected over the course of the entire winter, while land was selected least. Boat Ramp and Blackjack selected for water habitat and against land habitat throughout the entire winter season. Lobstick and Blackjack selected for edge habitat the entire winter. Land was typically selected against; however, PL and LS selected for this habitat type in Nov-Dec, and PL selected for land in Jan-Feb as well.

Figure 5. Area (ha) of each habitat type within the winter territory of 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA.

Figure 6. Percentage of each habitat type within the winter territory of 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA.

Table 10. Observed:Expected ratio for habitat selection of 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas USA. (+) indicates habitat was selected for, (-) indicates habitat was selected against, (=) indicates ratio was equal to 1.00.

Family	Month	Edge		Land		Water	
BR	Nov-Dec	1.23	(+)	0.63	(-)	1.56	(+)
	Jan-Feb	0.86	(-)	0.20	(-)	2.39	(+)
	Mar-Apr	1.02	(+)	0.62	(-)	1.63	(+)
PC	Nov-Dec	1.01	(+)	1.04	(+)	0.54	(-)
	Jan-Feb	1.94	(+)	0.84	(-)	1.01	(+)
	Mar-Apr	1.41	(+)	0.94	(-)	0.90	(-)
PL	Nov-Dec	0.98	(-)	1.71	(+)	0.43	(-)
	Jan-Feb	1.00	(=)	1.59	(+)	0.51	(-)
	Mar-Apr	0.89	(-)	0.65	(-)	1.38	(+)
LS	Nov-Dec	1.07	(+)	1.18	(+)	0.53	(-)
	Jan-Feb	1.19	(+)	0.86	(-)	1.12	(+)
	Mar-Apr	1.50	(+)	1.02	(+)	0.41	(-)
BJ	Nov-Dec	2.12	(+)	0.75	(-)	1.49	(+)
	Jan-Feb	1.75	(+)	0.77	(-)	1.97	(+)
	Mar-Apr	1.09	(+)	0.86	(-)	2.34	(+)

Percentages of each habitat type within the buffered movement paths show that all crane families spent a disproportionately greater amount of time in edge habitat throughout the entire winter season (Table 11). Open water composed 62% of the BR family movement paths in Jan-Feb, while open water made up only 34% of the territory. During the rest of the winter, the BR family used a smaller percentage of open water than was available. The reverse trend was seen for their use of land habitat – during Jan-Feb only 25% of the movement paths were composed of land, while 57% of the territory is land habitat. The PC family used a disproportionately smaller percentage of land habitat throughout the winter, and water habitat was only used at a greater percentage during Jan-Feb. The PL family's use of land habitat in Nov-Dec and Jan-Feb represented a larger percentage than what was available, while open water was not used more than its availability throughout the winter. The LS family used a greater percentage of land habitat in Nov-Dec and open water in Jan-Feb than what was available. Land habitat use by the BJ family was less than the available amount for the entire winter, while open water use was greater than the available amount (see Appendix B for ArcGIS maps of movement paths and habitat types).

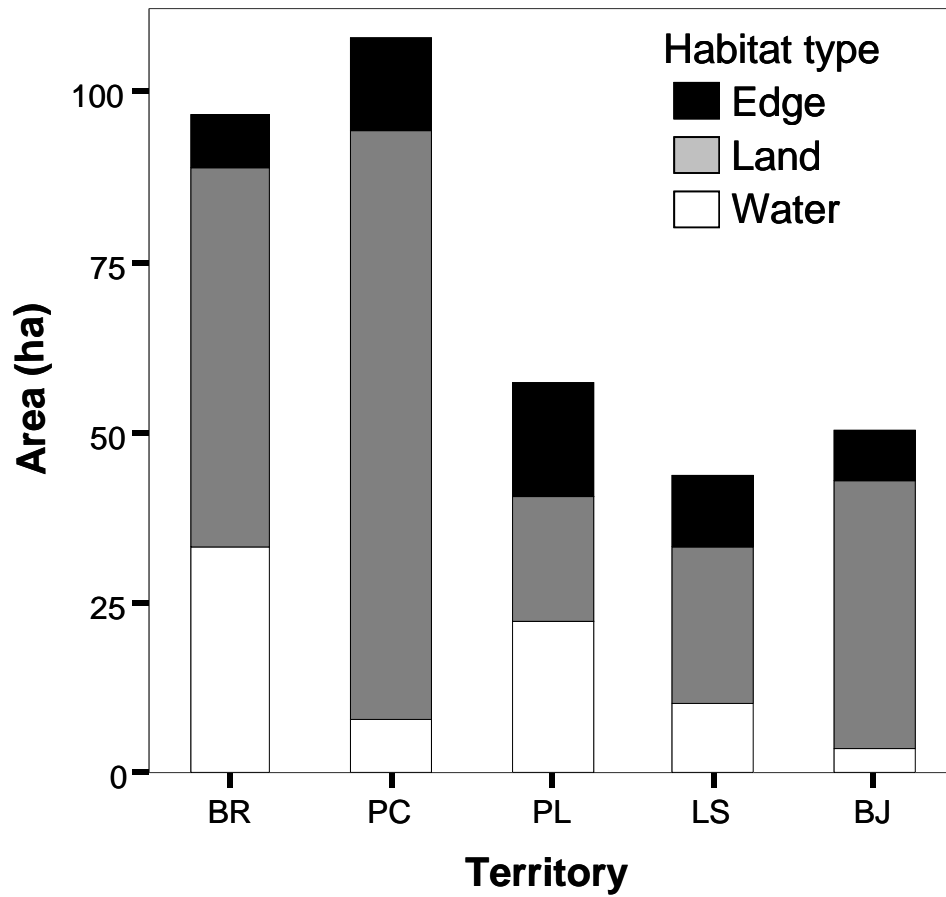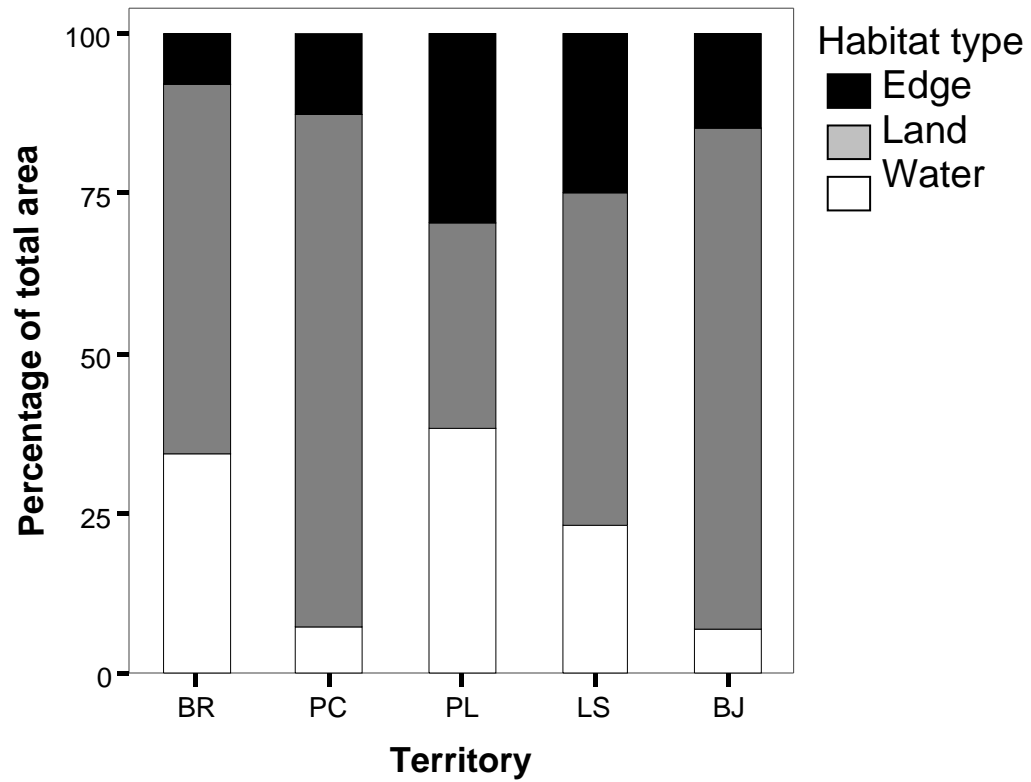Table 11. Percentage of each habitat type within area of movement path compared to percentage of each habitat type available in entire winter territory of 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA.

		Nov-Dec	Jan-Feb	Mar-Apr	Percentage of total territory
BR	Edge	10.69	11.48	11.92	7.91
	Land	64.01	25.78	59.41	57.82
	Water	25.30	62.74	28.67	34.27
PC	Edge	19.03	22.77	21.19	13.51
	Land	76.55	69.54	72.74	79.75
	Water	4.42	7.68	6.07	6.74
PL	Edge	32.60	31.96	34.98	29.45
	Land	38.30	40.62	29.26	32.10
	Water	29.10	27.42	35.76	38.45
LS	Edge	31.44	32.22	35.67	24.79
	Land	58.68	40.79	52.54	52.02
	Water	9.88	26.99	11.79	23.19
BJ	Edge	31.68	25.42	16.13	14.64
	Land	55.05	66.31	71.87	78.41
	Water	13.27	8.27	12.00	6.95

Spatial analysis of territories

A comparison of territory size (which was calculated using the Minimum Convex Polygon method) to the Kernel HR area (calculated based on the same location points used for Minimum Convex Polygon method) resulted in a far larger estimated territory size than that estimated by the Kernel HR method for 4 of the 5 families (Figure 7). Despite this difference in overall area, the percentage of each habitat type within the Kernel HR and Minimum Convex Polygon was nearly the same (Figure 8). The PC territory was most affected by the change in estimation method, with the Kernel HR area being less than half that of the territory size calculated using the Minimum Convex Polygon method.

Edge density, pond density, and landscape shape index (LSI) were highest at PL and lowest at BR (Table 12). Higher values of LSI indicate a more complex pattern of land and water, indicating that PL territory had the most complex landscape shape, followed by LS. When this statistic is combined with largest patch index (LPI), a clear difference between BR and PL can be seen. Both BR and PL had similar LPI sizes for land and water; however, the difference in LSI indicated that the BR territory was composed of one large, simple-shaped body of water, while the PL territory had a large but complex-shaped body of water. Edge density (m/ha) results also indicate that PL had a very complex pattern, as there was a very high amount of edge between land and water, while the other 4 territories had far lower edge density values. PC, LS and BJ all had similar values for pond density, which, based on the LPI, were all relatively small
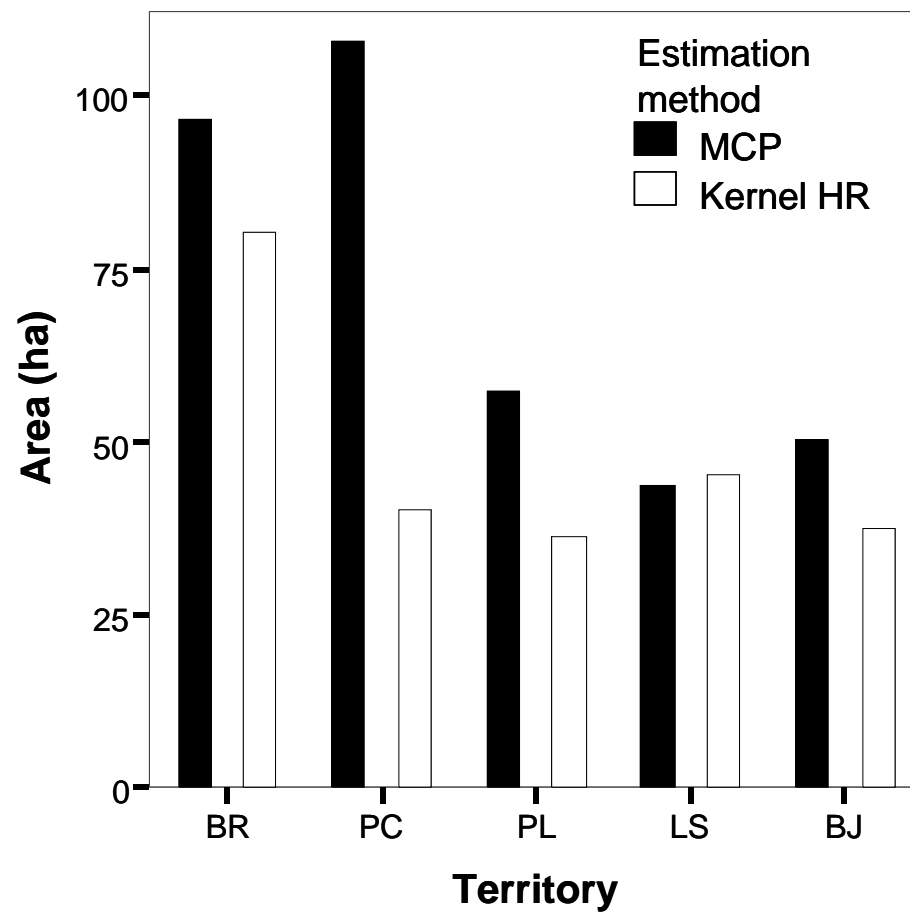
Figure 7. Comparison of winter territory size estimates using two methods: Minimum Convex Polygon (MCP) and Kernel Home Range (HR) for 5 whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA.
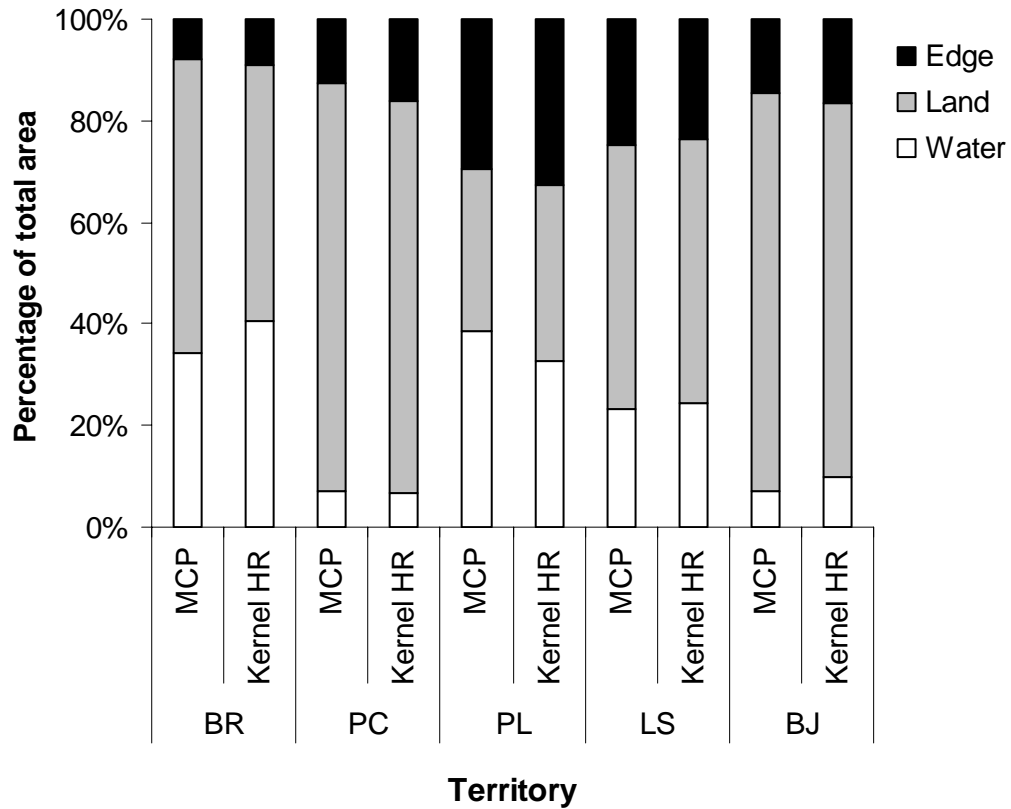
Figure 8. Percentage of each habitat type within the MCP and Kernel HR area for 5 whooping crane winter territories in 2003-2004 and 2004-2005 at ANWR, Texas, USA.

Table 12. Results of class and landscape metrics run in FRAGSTATS for 5 whooping crane winter territories in 2003-2004 and 2004-2005 at ANWR, Texas, USA. See Appendix A for definitions of metrics used.

Family	Edge Density (m/ha)	Largest Patch Index (% of total territory)		Pond Density (#/100ha)	Landscape Shape Index	Clumpiness (of ponds)
		Land	Water			
BR	77.02	48.59	33.94	99.39	3.59	0.96
PC	161.43	74.02	5.00	228.74	5.92	0.73
PL	367.28	47.16	44.40	365.58	9.92	0.84
LS	138.78	66.03	7.56	120.86	5.45	0.81
BJ	136.01	88.23	2.52	260.32	4.42	0.77

ponds. BR had the lowest density of ponds, yet the largest patch of water was approximately 1/3of the entire territory. The clumpiness index indicated that all ponds within the territories were aggregated to some degree. The highest possible value was 1, which means that the landscape was maximally aggregated. A value of zero indicates the ponds were randomly distributed. BR had the highest clumpiness index value of 0.96, while PC had the lowest value, 0.73, indicating that of all the territories, the ponds were the least aggregated at the PC territory.

Discussion

Spatial use of marsh habitat varied at each territory, with few clear patterns. With the exception of the PC family, movement velocity tended to be the lowest in Jan-Feb for each family. This is opposite of the hypothesized result that movement velocity would be greatest in Jan-Feb due to low food availability. There are several potential explanations. The first explanation is that food availability did not decrease enough to cause cranes to increase the distance traveled in search of food, which would have resulted in higher movement velocities. Movement velocity may also have been greater in Nov-Dec due to territorial defense, as hypothesized. In most cases, flight was the locomotory mode used in chasing away intruders, particularly at the beginning of the winter season. The frequency of flights, in terms of percentage of the total observation sessions, was highest at 4 of the 5 territories in Nov-Dec, and tended to decrease after this time, supporting the hypothesis that territorial establishment and defense would result in increased flight frequencies. Locomotion may also have increased during this

time, as cranes were more alert and attentive to the maintenance of their territorial boundaries. Movement and flight frequency may have increased in Mar-Apr as spring migration approached, and the cranes grew more restless.

Another possible explanation of reduced movement velocities incorporates habitat selection. The peak of wolfberry fruit production in early winter seems to have been reflected in the selection of land habitat by several crane families. While land habitat was typically selected against, it was selected for in Nov-Dec by PL and LS, and PC used it equal to its availability, which may indicate that cranes focused on finding and consuming wolfberry fruits during this time. After Nov-Dec, land habitat was typically selected against, at which time cranes focused on capturing blue crabs in open water or along the water's edge. Edge habitat appears to be an important foraging habitat, as most territories selected for it at some point throughout the winter season, if not for the entire season. Switching habitats depending on food availability may explain the decrease in movement velocity in Jan-Feb. By Mar-Apr food resources may have been depleted, causing an increase in movement velocity as cranes traveled further in order to obtain adequate food. A spring influx of blue crabs typically moves into the marsh ponds in late March or April (D. Rutka, pers. comm.), at which time the cranes would most likely have focused on pursuing and consuming crabs until migration.

The variation in spatial pattern among territories makes it difficult to generalize about the minimum requirements of a wintering "territory" for a family of cranes; however, it is apparent that a wide array of spatial patterns can provide adequate wintering habitat. Boat Ramp territory contained one very large body of water, Redfish

Slough, unlike any other territory studied, and the BR family selected for open water throughout the winter. The preferential use of open water by the BR family is most likely explained by the alternative food source available in Redfish Slough, that being clams (*Tagelus plebius* and *Rangia* clams), which are commonly consumed by whooping cranes (Nelson et al. 1996). The majority of food items obtained by cranes foraging in Redfish Slough were clams (personal observation); however, several crabs were also caught, as well as snakes on occasion. No other territory studied had a body of water comparable to Redfish Slough, and a previous study reported that clams were not found in smaller ponds in the salt marsh, but only in larger bays (Chavez-Ramirez 1996). The BR family exhibited a strong shift in habitat use to open water in Jan-Feb in response to foraging opportunities available within their territory.

Pump Canal and Blackjack territories were similar in composition, as both were primarily composed of land habitat, and the open water that was present was primarily small ponds, which were the least aggregated of all territories studied. The families maintaining these territories may have had limited food resources, due to the small area of water available within the territory. The most important food items available in vegetation are wolfberry fruits, which are no longer available after December (Chavez-Ramirez 1996; Butzler 2006). This places a greater pressure on blue crabs for the rest of the winter season; however, with a smaller area of water there is less available habitat for the crabs to occupy, which may partially explain the increasing movement velocity of the PC family as the season progressed. The limited open water and edge habitat at the PC territory may also explain why their movement velocity is typically the highest of

all families, as they may have been forced to spend a greater amount of time searching for the few crabs that were in their territory. The smaller area of open water and edge habitat within the PC territory may have resulted in the family depleting their food resources earlier than the other families, causing the movement velocity to increase throughout the winter.

The BJ territory has similar landscape characteristics to PC territory, but it is difficult to draw conclusions about the movement patterns of the BJ family for several reasons. Previous data indicated that the BJ territory was not consistently used from year to year, unlike most other whooping crane territories (Bonds 2000). The BJ family only utilized this area during winter 2003-2004, and was often absent from the territory. The location of the family during these occurrences is unknown. The inconsistent use of the area suggests that the BJ territory is of marginal quality, and cannot always support a crane family throughout the winter season.

Landscape characteristics of the PL territory were different from the other territories discussed thus far in terms of the proportion of habitat types and complexity of edge habitat. The area was nearly evenly distributed among the three habitat types, and based on the Largest Patch Index, much of the water was connected. The preferential use of land habitat by the family in Nov-Dec and Jan-Feb suggest they focused on finding and consuming wolfberry fruits while they were available. Based on the Observed:Expected ratio, the PL family was the only one that did not select for edge habitat at any time during the winter; however, the family did use edge habitat

proportional to its availability for most of the winter. PL had the highest percentage of edge habitat, suggesting that the amount of edge available in the territory was sufficient.

The LS territory, which was the smallest, tended to have the median value of the 5 territories studied for most landscape characteristics, but had the second highest percentage of edge. The location of the LS territory is unique, as it is a long, thin peninsula, surrounded on 3 sides by water (GIWW on one side, Dunham Bay on the other 2 sides). The tendency of the LS family to fly long distances is most likely due to the physical distance from their territory to another area of salt marsh. The family often flew to another location within their territory, but if they left the territory, they had to fly either across Dunham Bay or across the GIWW and the dredge island to the salt marsh found on the far shore of the dredge island. Both distances were substantial (>750 m), and may in part explain the low percentage of flight occurrence exhibited by the family. Leaving the territory would be an energetically costly activity, which maybe have been avoided by the LS family. This changed in Mar-Apr, when flight occurred in 20% of observation sessions, which may be explained by greater amounts of human activities (see Chapter IV) occurring during that time.

CHAPTER IV

BEHAVIORAL RESPONSE OF WHOOPING CRANES

TO HUMAN ACTIVITIES

Introduction

Studies have shown that human activities occurring in proximity to wintering

birds can have adverse affects on behavior, primarily by reducing foraging time, and

increasing high energy behaviors (Carney & Sydeman 1999). Birds have also been

shown to shift from preferred to less preferred feeding areas due to human disturbance

(Hockin et al. 1992). Significant declines in time spent foraging could potentially

decrease reproductive success during the following breeding season; however this is

difficult to assess (Hill et al. 1997). Whooping cranes wintering on the Texas coast are

exposed to frequent human activities in close proximity to their wintering territories

(Mabie et al. 1989). While previous studies indicated that recreational activity had not

caused cranes to alter their habitat use (Mabie et al. 1989), this may not mean that crane

behavior is not affected by disturbance. The salt marsh habitat, in which cranes maintain

winter territories, is located along the land/water interface of the coast (Stehn & Johnson

1987). There is little other suitable habitat that cranes could escape to that would be

disturbance-free, which may force them to remain in areas where human activities occur,

regardless of how it affects them (Gill et al. 2001).

The GIWW, a heavily used shipping channel, runs parallel to most whooping

crane territories located on the Blackjack Peninsula of the Aransas NWR, and provides

boating access to many bays adjacent to crane territories. The impact of human activities associated with GIWW traffic on the behavior of crane families is important for assessing the threats to the continued recovery of the species. The objective of this study was to determine the relationship of changes in behavior of whooping crane families in response to human activities on the wintering grounds. I hypothesized that foraging behavior would decrease and alert behavior would increase with increasing levels of human activities (both in terms of frequency of stimuli, and reaction to high-intensity stimuli).

Methods

Human activities were recorded opportunistically during behavioral observation sessions, due to the lack of control over the timing of human activities near crane territories. Activities that fit the following criteria were referred to as "human stimuli" or "stimuli": stimulus is visible from territory (not only audible) and is within 750 m of territory boundary. Unless activities met these criteria, they were not recorded as a human stimulus and were therefore not evaluated for behavioral response. The following types of human stimuli were recorded: small motor boats, medium motor boats, large motor boats, airboats, tour boats, sailboats, shrimp boats, barges, barge tugboats, helicopters, airplanes, motor vehicles, and humans on foot. During each event, the type, proximity, duration, travel direction, and intensity of the stimulus were recorded.

Intensity was a subjective measure, and was determined by the speed, proximity, and auditory volume of the stimulus, similar to the disturbance categorization described by Hockin et al. (1992) (Figure 9). There were three levels of intensity: low, medium, and high. A low intensity stimulus is one that had low or quiet sounds associated with it, was relatively far away from the crane territory, and did not alter path or speed (movement is constant or steady). A high intensity stimulus was typically loud, close to the crane territory, and moved erratically. Medium intensity stimuli occurred when the activity had a combination of low and high intensity characteristics, for example, one that was loud, but was far away from the territory.

Human stimulus patterns were evaluated for each territory by summarizing the frequency (number of stimuli per hour), type, and duration of stimuli that occurred at each territory. The percentage of low, medium, and high intensity stimuli that occurred at each territory was also calculated. Stimulus patterns in each month category (Nov-Dec, Jan-Feb, and Mar-Apr) were calculated to determine temporal changes in human activities near crane territories.

Data analysis

Statistical procedures were performed in SPSS version 11.0 (SPSS, Chicago). Duration of stimuli at each territory was log-transformed, and then compared using a one-way ANOVA. Duration of motor-boat stimuli was compared using Kruskal-Wallis and Mann-Whitney U tests, as data were non-normal at each territory. Frequency of human stimuli at each territory was compared using a Kruskal-Wallis test, with Mann-
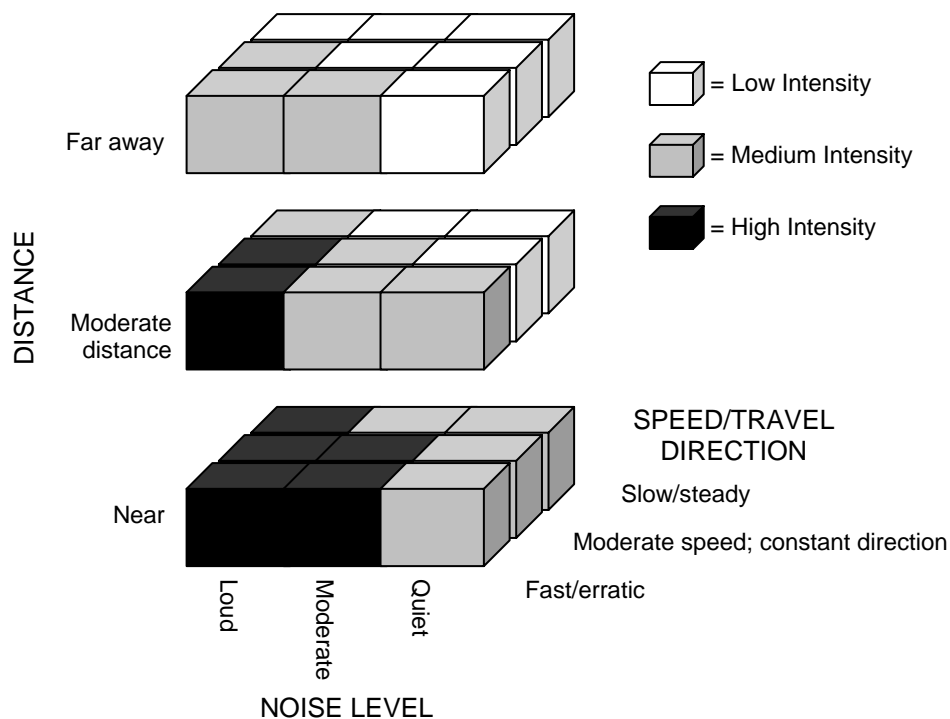
Figure 9. Conceptual diagram of intensity categories. Noise level, distance, and speed/travel direction were evaluated for each disturbance; intersection point determined intensity level.

Whitney U used as a post hoc test. Statistical analyses were performed on 1,019 stimuli that occurred during winter 2003-2004 and 2004-2005. Small, medium and large motor boats were grouped into a "Motor boat" category for analysis. Airplanes and helicopters were also grouped.

Individual crane behaviors were averaged for each observation session, allowing each family group to be evaluated for behavioral response. Response to human stimuli was determined in two ways. The potential effect of stimuli frequency on crane behavior was determined by comparing the mean proportion of time spent in four main

activities (Foraging, Alert, Comfort, and Movement) for sessions when no stimuli occurred with mean values recorded during sessions with different numbers of stimuli (Galicia & Baldassarre 1997). Numbers of stimuli that occurred in a session were categorized into three groups: 1-2, 3-5, or > 5 stimuli. A Kruskal-Wallis test was used to compare groups; a Mann-Whitney U test was used post-hoc to determine where differences occurred if significant variance was detected in the Kruskal-Wallis test. The second approach used for evaluating behavioral response compared proportion of time spent in each activity before, during, and after high intensity stimuli occurred (Galicia & Baldassarre 1997). Only high intensity stimuli lasting at least 2 min were used in the analysis. Kruskal-Wallis was used to determine if behavior varied significantly between the three categories. If a statistically significant difference was detected, a Mann-Whitney U test was used post-hoc to determine which groups significantly varied from others.

Results

Activity patterns

The most common type of human stimulus was motor boats, representing approximately 50% of all stimuli that occurred (Table 13). Barges were the second most common stimuli, representing 18% of all stimuli. Other common types include shrimpboats, airboats, tourboats, and airplanes and helicopters. Stimuli that rarely occurred were barge tugs, sailboats, motor vehicles, and humans on foot (each less than 1% of all stimuli that occurred).

Duration of motor boats varied significantly by territory (p < 0.001). Median

duration at LS and BJ territories was significantly lower than BR, PC and PL territories

(p < 0.001), and PL was significantly lower than PC territory (p = 0.009) (Table 14).

Table 13. Frequency and percentage of all stimuli types that occurred
during winter 2003-2004 and 2004-2005 at 5 whooping crane territories
at ANWR, Texas, USA.

Stimuli type	Frequency	Percent
Small motor boat	435	42.69
Medium motor boat	59	5.79
Large motor boat	13	1.28
Barge	191	18.74
Barge tug	8	0.79
Shrimpboat	59	5.79
Airboat	36	3.53
Tourboat	89	8.73
Sailboat	6	0.59
Airplane	64	6.28
Helicopter	47	4.61
Vehicle	10	0.98
Human	2	0.20
Total	1019	100

Table 14. Mean duration (min:sec) of 6 common human stimuli occurring in close proximity to 5 whooping crane winter territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. n = number of events recorded for each type at each territory. SE = Standard Error of the Mean.

Territory		Motor boats	Barges	Shrimpboats	Airboats	Tourboats	Airplanes/ Helicopters
BR	Duration	1:28	7:01	3:20	n/a	8:15	1:03
	n	59	39	14	0	6	27
	SE	7.8	19.3	26.1	-	128.4	6.8
PC	Duration	1:39	6:44	5:12	2:05	3:53	1:00
	n	94	53	18	3	23	30
	SE	8.3	24.2	25.0	25.0	36.8	5.7
PL	Duration	1:17	7:43	3:39	2:38	3:21	0:53
	n	133	46	14	11	23	22
	SE	7.4	26.3	24.2	32.7	29.4	5.0
LS	Duration	1:26	5:11	2:54	1:57	16:06	0:56
	n	167	53	13	14	37	29
	SE	13.2	26.3	22.4	16.4	129.4	7.7
BJ	Duration	1:13	n/a	n/a	2:04	n/a	0:45
	n	5	0	0	8	0	3
	SE	15.3	-	-	27.0	-	8.7
Average		1:25	6:28	3:53	2:12	9:07	0:58

Duration of airboats and airplanes/helicopters did not vary significantly by territory (p = 0.642, 0.807, respectively). Airboat duration averaged 2 min. 12 sec., and airplanes/helicopters averaged 58 sec. Duration of barges, shrimpboats and tourboats varied significantly (p = 0.002, 0.001, 0.000, respectively) by territory. Barges passing the LS territory were of significantly shorter duration that those at BR, PC and PL territory. Shrimpboat duration was significantly greater at PC territory than at BR, PL and LS territories. Tourboat duration was significantly greater at LS territory than at BR, PL and PC territories. BJ territory did not experience barge, shrimpboat or tourboat traffic, as it is located further away from the GIWW than other territories.

Overall, stimuli frequency averaged 3.53 per hour. Frequency of stimuli was significantly higher at the LS territory than at the other 4 territories (p < 0.001) (Figure 10). Frequency was also higher at PC than BR (p = 0.034). Throughout the winter, stimuli frequency varied at the PC and LS territories (p = 0.001, 0.002, respectively) (Figure 11). The number of stimuli per hour was significantly higher in Mar-Apr than in Nov-Dec and Jan-Feb at both territories (p ≤ 0.001).

Intensity of stimuli tended to be similar at most territories, with the exception of the LS territory. Low intensity stimuli made up 82-86% of all stimuli that occurred at BR, PC, PL and BJ territories (Table 15). At the LS territory, 8.2% of the stimuli that occurred were low intensity, while 72.2% were medium intensity, and 19.6% were high intensity. At the remaining 4 territories, medium and high intensity stimuli averaged 11.4% and 4.6% of all stimuli that occurred, respectively. In total, 75 high intensity stimuli occurred. Fifty-seven percent of all high intensity stimuli occurred at the LS

territory. Pipeline territory had 21% of all high intensity stimuli, and BR, PC, and BJ

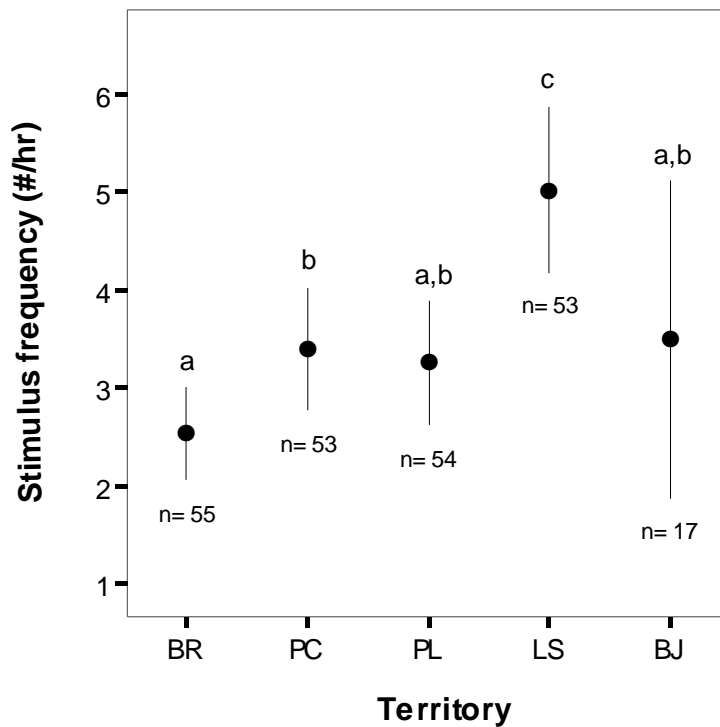territory had 5%, 6%, and 9% occur, respectively.

Figure 10. Mean number of stimuli per hour at 5 whooping crane winter territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. Error bars show Mean + 2.0 Standard Errors. n = number of day periods (i.e. early morning, late morning) spent at each territory. Means with the same letters are not statistically different.
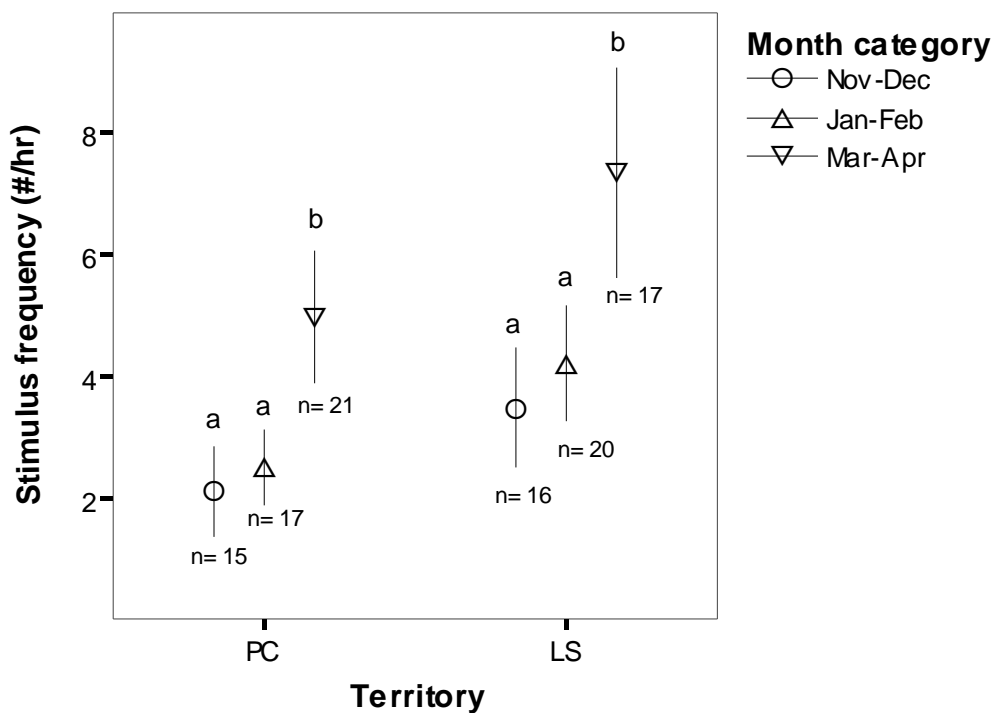
Figure 11. Mean number of stimuli per hour during each month category at PC and LS whooping crane winter territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. Error bars show Mean + 2.0 Standard Errors. n = number of day periods (i.e. early morning, late morning) spent at each territory in each month category. Means with the same letters are not statistically different.

Table 15. Percentage of low, medium, and high intensity stimuli that occurred throughout winter season at 5 whooping crane territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. n = number of events.

Territory	Low intensity		Medium intensity		High intensity	
	%	n	%	n	%	n
BR	82.6	128	14.8	23	2.6	4
PC	86.2	193	11.6	26	2.2	5
PL	83.7	216	10.1	26	6.2	16
LS	8.2	26	72.2	229	19.6	62
BJ	83.0	54	6.2	4	10.8	7

Behavioral response

Stimulus frequency did not result in a decrease in foraging behavior or an increase in alert behavior, the hypothesized effect. When data for all families were combined, there were no differences in foraging, alert, comfort or movement behaviors as stimulus frequency increased. When data were evaluated by family group, several families showed negative responses to increasing stimulus frequency (Table 16). Proportions of time spent in each activity were not evaluated by month category, due to the small sample size for several stimulus frequency categories. Boat Ramp, Pipeline and Blackjack families did not alter their behavior as stimulus frequency increased (Figure 12). The Pump Canal family exhibited significant differences in foraging and alert behavior; however, the result was opposite of the hypothesized effect (Figure 13). Proportion of time spent foraging by the PC family was significantly lower when 0 stimuli occurred than when 1-2, 3-5 and >5 occurred ($p \leq 0.021$), and alert behavior was significantly greater when 0 stimuli occurred than when 1-2 or 3-5 occurred ($p \leq 0.016$). Movement behavior by the LS family was significantly higher when > 5 stimuli occurred than when 0, 1-2, and 3-5 occurred ($p \leq 0.003$) (Figure 14).

Table 16. Mean proportion of time spent in 4 main activities during increasing stimulus frequency at 5 whooping crane territories. 0, 1-2, 3-5, and >5 refer to the number of stimuli that occurred in a 30-min observation session. n = number of observation sessions during which each given stimulus frequency occurred. SE = Standard Error of the mean.

| Family	# dist.	n	Foraging		Alert		Comfort		Movement	
			Mean	SE	Mean	SE	Mean	SE	Mean	SE
BR	0	63	0.66	0.022	0.14	0.012	0.09	0.017	0.08	0.012
	1-2	113	0.63	0.022	0.18	0.011	0.09	0.520	0.08	0.008
	3-5	23	0.63	0.410	0.18	0.027	0.13	0.320	0.06	0.015
	>5	4	0.70	0.083	0.22	0.062	0.06	0.037	0.02	0.006
PC	0	56	0.63	0.028	0.18	0.015	0.04	0.010	0.09	0.009
	1-2	88	0.73	0.016	0.13	0.008	0.03	0.006	0.08	0.007
	3-5	57	0.76	0.023	0.13	0.012	0.02	0.006	0.08	0.009
	>5	5	0.85	0.053	0.09	0.314	0.02	0.016	0.03	0.024
PL	0	36	0.70	0.037	0.13	0.021	0.04	0.015	0.06	0.009
	1-2	61	0.63	0.030	0.16	0.016	0.05	0.012	0.07	0.008
	3-5	33	0.67	0.041	0.13	0.016	0.08	0.025	0.05	0.007
	>5	8	0.75	0.074	0.07	0.016	0.07	0.047	0.08	0.032
LS	0	26	0.67	0.048	0.15	0.031	0.07	0.021	0.04	0.009
	1-2	74	0.64	0.020	0.15	0.014	0.11	0.022	0.05	0.009
	3-5	67	0.69	0.028	0.16	0.017	0.08	0.015	0.04	0.005
	>5	19	0.71	0.034	0.13	0.020	0.03	0.011	0.08	0.012
BJ	0	21	0.56	0.056	0.24	0.056	0.06	0.023	0.10	0.018
	1-2	15	0.65	0.056	0.13	0.024	0.03	0.020	0.12	0.027
	3-5	5	0.63	0.122	0.26	0.093	0.06	0.058	0.04	0.018
	>5	-	n/a	-	n/a	-	n/a	-	n/a	-
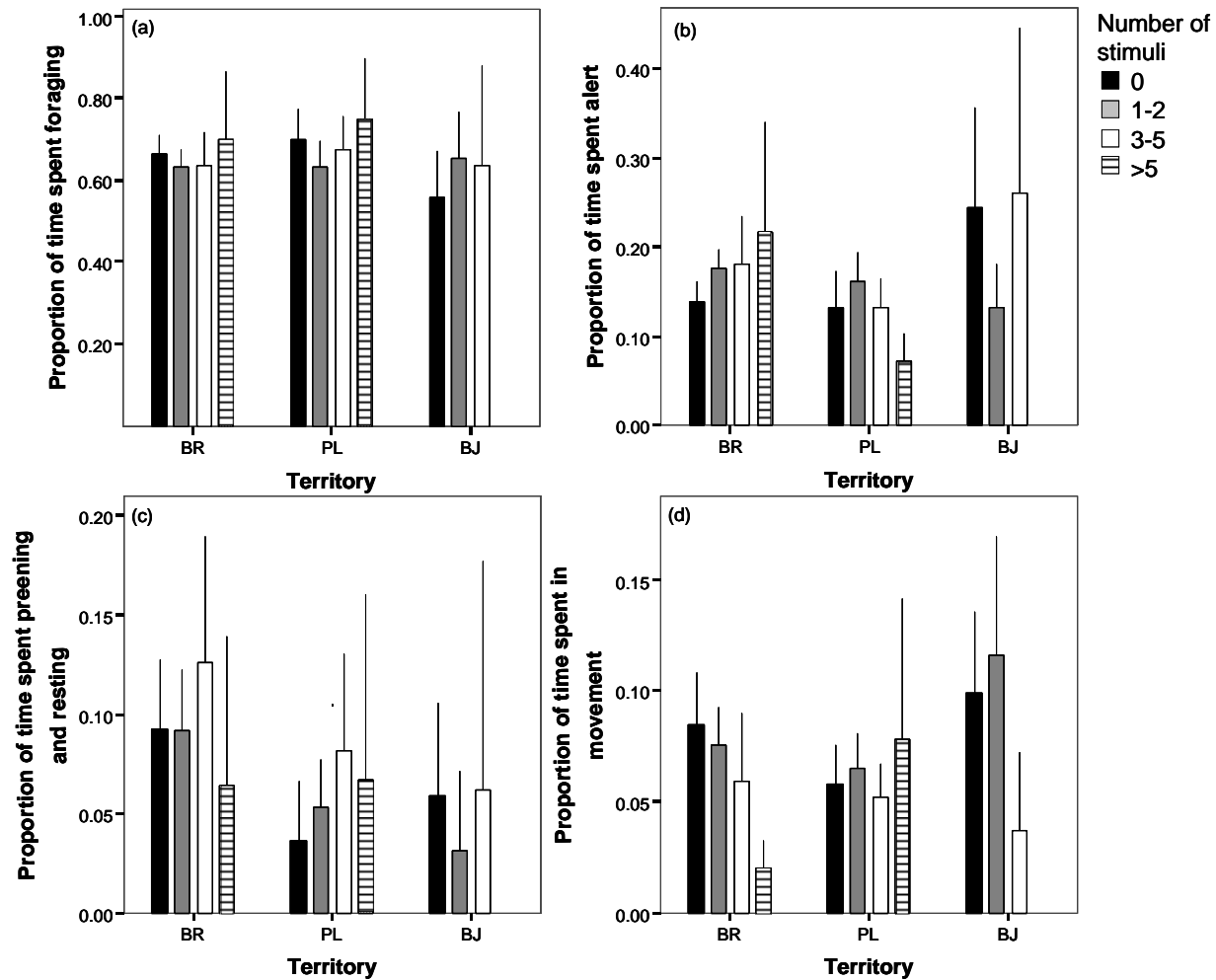
Figure 12. Proportion of time spent foraging (a), alert (b), preening and resting (c) and in movement (d) during varying levels of stimulus frequency by BR, PL and BJ whooping crane families during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. Error bars show the Mean + 2.0 Standard Errors. No significant changes in the 4 behaviors were detected at different stimuli frequencies for these families.
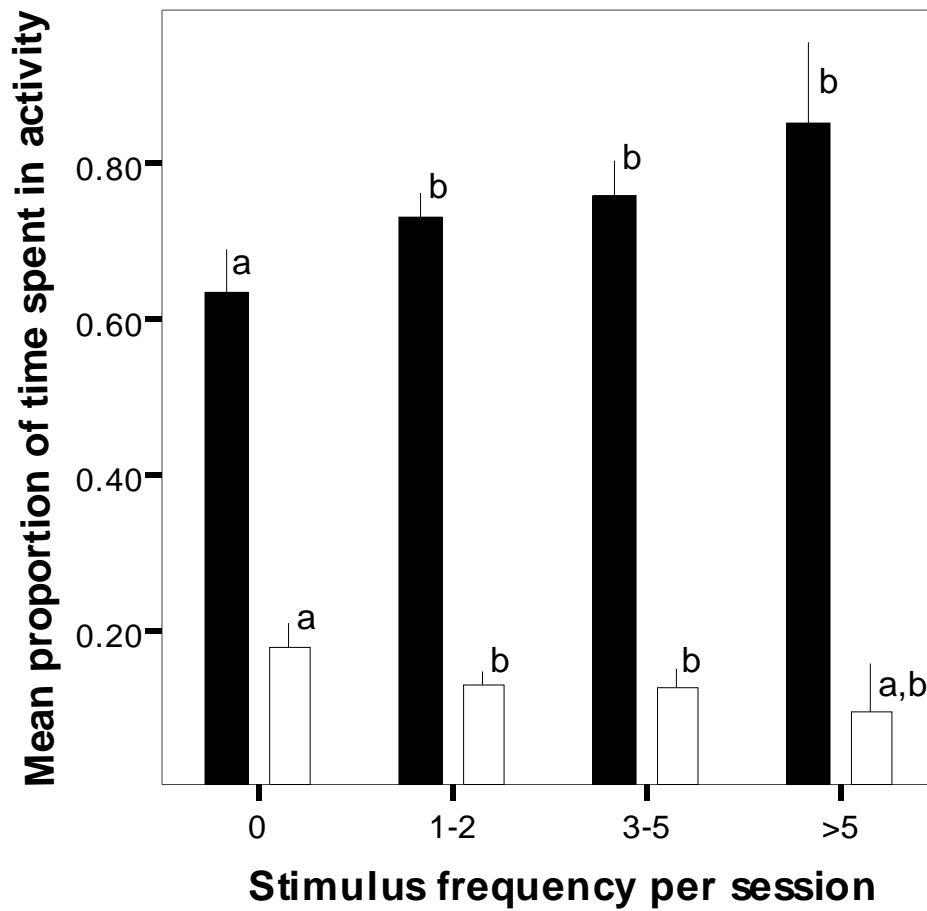
Figure 13. Mean proportion of time spent foraging (black bars) and alert (white bars) by PC family as stimulus frequency increased during winter 2003-2004 and 2004-2005. Error bars show the Mean + 2.0 Standard Errors. For each activity, means with the same letter are not statistically different.
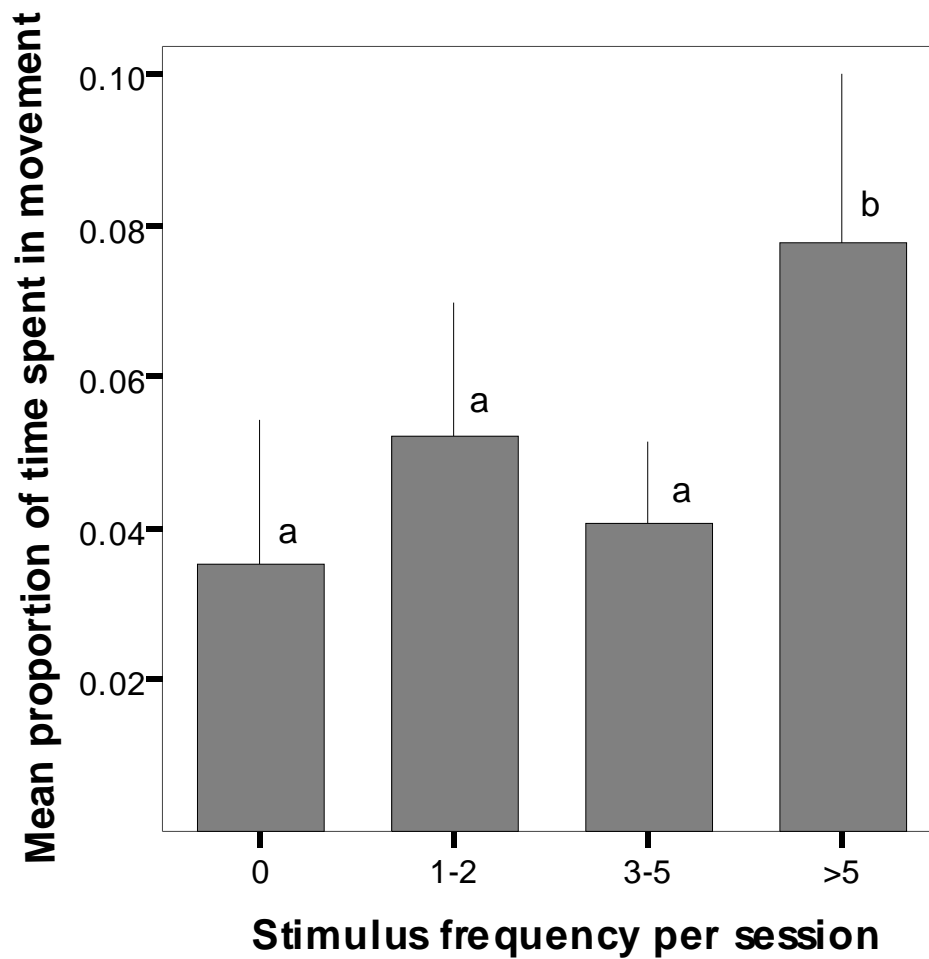
Figure 14. Mean proportion of time spent in movement by the LS family as stimulus frequency increased during winter 2003-2004 and 2004-2005. Error bars show the Mean + 2.0 Standard Errors. Means with the same letter are not statistically different.

Juvenile behavior did not vary significantly before, during or after high intensity stimuli occurred. Occurrence of high intensity stimuli did not result in significant changes in behavior by PL, LS or BJ adults when all month categories were combined; BR and PC adult behavior did vary (Table 17). Boat Ramp adults spent significantly less time foraging during high intensity stimuli than they did before the stimuli (p = 0.02). Alert behavior of Pump Canal adults was significantly higher before high intensity stimuli than during the stimuli (p = 0.041). When data were evaluated for each family and month category, there were several significant changes in behavior at PC, PL and LS. In Nov-Dec, PL adult foraging behavior was significantly reduced during high intensity stimuli (p = 0.021). After the stimuli, proportion of time spent foraging returned to nearly the original levels (Figure 15). At LS, movement behavior in Jan-Feb was significantly higher before high intensity stimuli than during or afterwards (p ≤ 0.042) (Figure 16). In Mar-Apr, proportion of time spent foraging by LS family was lowered during a stimulus; however, the change was not significant. After the stimulus occurred, foraging increased significantly from the level observed during the occurred of the stimulus (p = 0.011) (Figure 15). Comfort behavior also varied – proportion of time spent preening and resting was significantly higher during a high intensity stimulus than after one (p = 0.050) (Figure 16).

Table 17. Mean proportion of time spent in 4 main activities before, during and after high intensity stimuli occurred at 5 whooping crane territories during winter 2003-2004 and 2004-2005 at ANWR, Texas, USA. ** indicates a significant difference in proportion of time spent in a given behavior at the territory.

	Boat Ramp			Pump Canal			Pipeline		
	Before	During	After	Before	During	After	Before	During	After
Foraging	0.813	0.225**	0.632	0.579	0.338	0.459	0.671	0.484	0.726
Alert	0.104	0.497	0.301	0.127	0.037**	0.333	0.153	0.229	0.119
Comfort	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.210	0.071
Movement	0.084	0.278	0.068	0.174	0.200	0.000	0.010	0.076	0.764

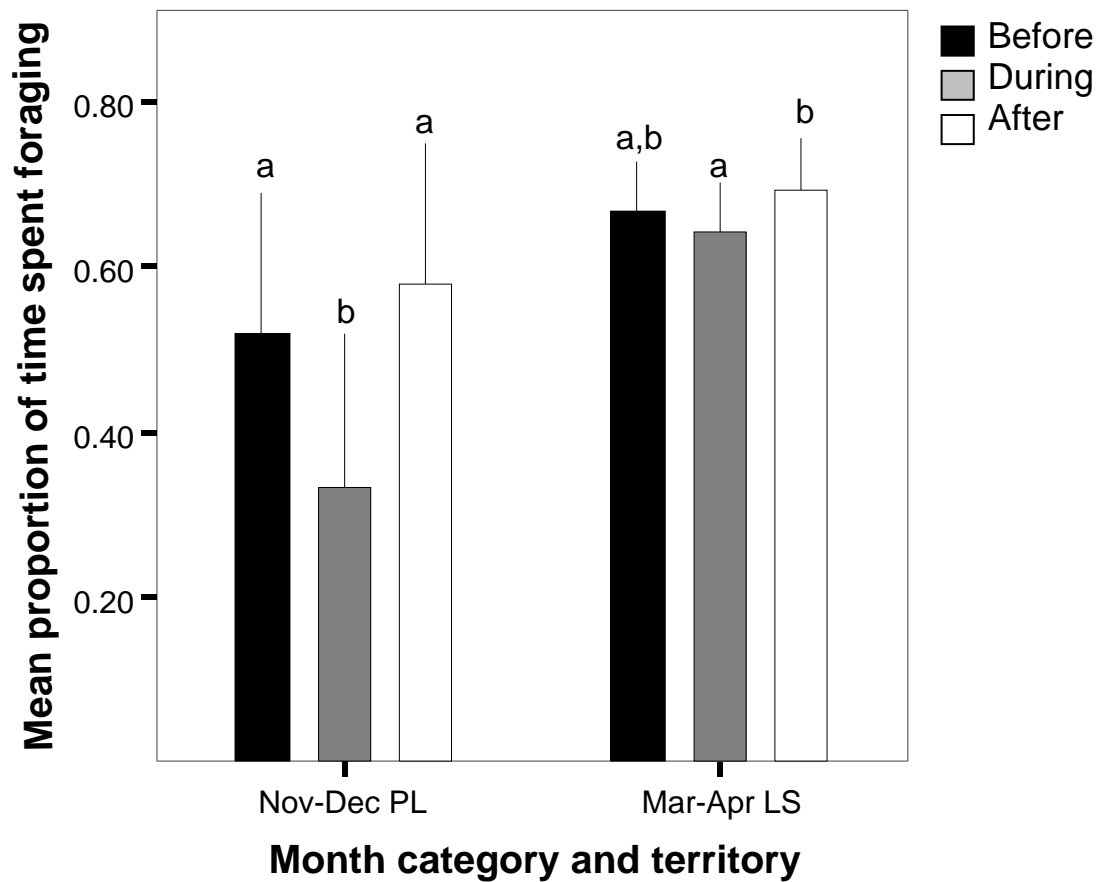|	Lobstick			Blackjack		
	Before	During	After	Before	During	After
Foraging	0.659	0.650	0.694	0.680	0.544	0.585
Alert	0.142	0.154	0.150	0.181	0.319	0.149
Comfort	0.077	0.075	0.058	0.017	0.000	0.000
Movement	0.071	0.054	0.057	0.107	0.137	0.178

Figure 15. Reduction in mean proportion of time spent foraging during high intensity stimuli at PL and LS territories in Nov-Dec and Mar-Apr, respectively, during winter 2003-2004 and 2004-2005. Error bars show the Mean + 2.0 Standard Errors. For each territory, means with the same letter are not statistically different.
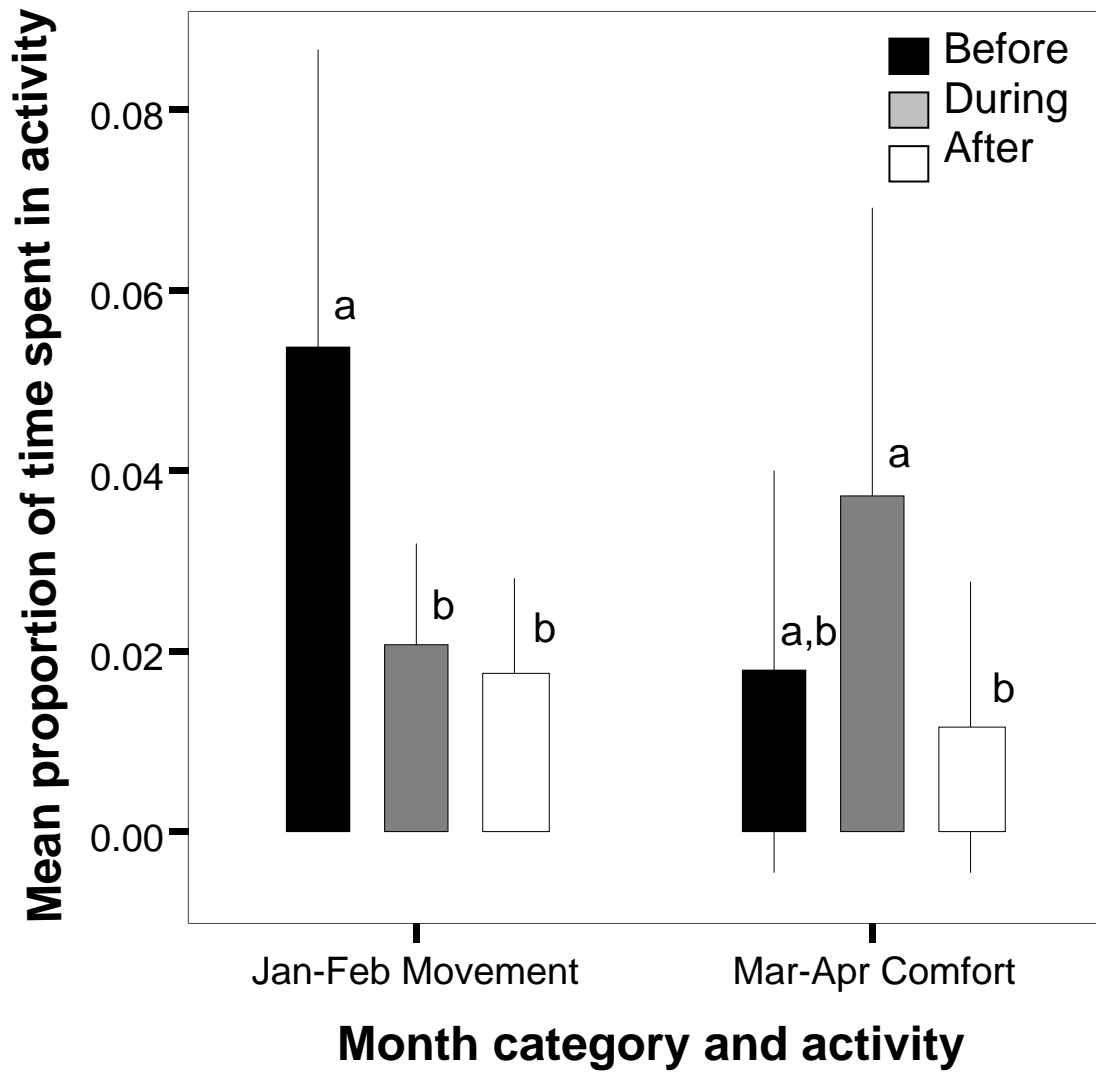
Figure 16. Variation in mean proportion of time spent in movement and comfort behaviors during high intensity stimuli at LS territory during winter 2003-2004 and 2004-2005. Error bars show the Mean + 2.0 Standard Errors. For each activity, means with the same letter are not statistically different.

Discussion

The LS territory had the highest stimulus level in terms of frequency, duration, and intensity of human stimuli. Seasonal trends showed that stimuli increased in Mar-Apr, most likely due to increased recreational motor boat traffic. Medium and high intensity stimuli were more common at the LS territory because of the close proximity of the GIWW, which ran adjacent to the territory. The section of the GIWW adjacent to the LS territory is narrow, which meant that any boat traveling in the GIWW was close to the territory boundary and therefore was considered a medium intensity stimulus, at minimum. Low intensity stimuli at the LS territory were primarily in the form of airplanes/helicopters and the occasional motor boat in the open bay between the LS territory and the Blackjack Peninsula. The other 4 territories were separated from the GIWW traffic by large open bays or by an upland burm (in the base of the BR territory), increasing the distance to many stimuli, or decreasing the visibility (in the case of the burm). Tourboat duration was significantly longer at the LS territory. Due to the close location of the LS family to the GIWW, tourboats were able to see the crane family well and often would stop daily for a considerable period in order to observe the cranes. The remaining 4 territories were somewhat similar in the type, duration, frequency and percentage of low, medium and high intensity stimuli that occurred.

The hypothesized effect of increasing alert behavior as stimulus frequency increased cannot be supported based on the results of this study. While there was no significant change in foraging behavior as stimulus frequency increased, the LS family exhibited significantly higher levels of movement when more than 5 stimuli occurred

within a 30-min observation session. Locomotion and flight are the two most energetically expensive behaviors for whooping cranes (Chavez-Ramirez 1996), and the increase in movement appeared to be at the expense of comfort behaviors, which includes resting. In the case of Pump Canal, the opposite response was observed, as foraging behavior was significantly lower during sessions when no human stimuli occurred, and alert behavior was significantly greater.

Behavioral response to high intensity stimuli was limited to specific month categories and families. Foraging behavior of the PL family in Nov-Dec and the LS family in Mar-Apr was lowered during high intensity stimuli. The proportion of time spent foraging after a high intensity stimulus did not vary significantly from time spent foraging before the high intensity stimulus occurred. High intensity stimuli were not common at the PL territory, making up 6% of all stimuli that occurred, which may have made the family more sensitive to high intensity stimuli. The LS family also significantly reduced movement in Jan-Feb and increased comfort in Mar-Apr in response to high intensity stimuli. The increased comfort behavior during a high intensity stimulus may be a displacement behavior, which could also result in the significant reduction in movement during the stimulus.

Several factors may have contributed to the responses exhibited by the LS family to human stimuli. Among these factors are that the LS territory experienced the highest frequency of human stimuli and the highest number of high intensity stimuli of the 5 territories studied; and stimuli frequencies were significantly higher in Mar-Apr, when high intensity stimuli were found to affect foraging behavior. I believe these changes in

movement and foraging behavior could negatively affect the over-winter condition of the LS family in years when food availability is reduced; however, based on the reproductive success of the LS adult pair, I do not believe they are significantly affected by the current level of human activities. During both years of this study, the LS pair successfully raised offspring, including twins in 2003-2004, which rarely survive (Miller 1973).

Anecdotally, humans on foot appeared to have the greatest negative effect on the cranes. This only occurred twice during data collection, but was seen approximately 5 times over the course of both winters. In each instance the cranes reacted by being alert, alarm calling, and flying away from the territory and out of sight. Most marsh habitat that contains whooping crane territories was protected, and the number of humans walking in the marsh was low. During this study, the only humans seen in the marsh were scientific researchers and refuge staff.

Comparisons of behavioral responses among month categories were difficult, due to the small sample size of high intensity stimuli at some territories. Significant differences in behavior within a month category should be critically evaluated, as negative response to high intensity stimuli could have been more a factor of small sample size than actual behavioral response. The overall analysis of behavior before, during and after a high intensity stimulus indicated there were minor changes in behavior, however no consistent patterns across families.

The limited response to human stimuli may indicate several things. First, the majority of human stimuli that occurred in close proximity to territories on the Blackjack

Peninsula are common occurrences, and can be seen as a "predictable" occurrence. This predictability may allow cranes to become habituated to them. It is when an uncommon activity occurs that a response is more likely to be seen. For example, the presence of a human on foot within the salt marsh caused a severe reaction each time it occurred. The frequency of this stimulus type was low, and its unpredictability may have been the cause for alarm. Tourboats and airboats, which were typically high intensity stimuli, particularly at the LS territory, did not elicit a strong negative reaction for the most part. In the disturbance study conducted by Mabie et al. (1989), the percent of time a crane family spent alert during a disturbance decreased over time, and typically, by the end of the disturbance, the percentage of alert behavior was equal to the control, when no disturbance was occurring. The decline in alert behavior during a disturbance indicates that the cranes habituated to the presence of a disturbance event while it was still occurring (Mabie et al. 1989). Mabie et al. (1989) also found that cranes did not significantly increase their alert behavior to 2 of the 3 disturbance types evaluated – only airboats elicited a negative response. A similar result, such as behavior returning to pre-stimulus levels during a stimulus, seems likely in the case of common activities occurring along the GIWW.

The second potential explanation for a limited response to human stimuli involves territoriality. The study by Mabie et al. (1989) found that disturbance did not cause cranes to leave their territories, although several families flew to the edge (or past) the boundary of their territory, and an aggressive encounter with neighboring cranes occurred. The fact that whooping cranes are territorial complicates research on the

effect of human activities on their behavior, as a crane pair may be less likely to leave an area they actively defend, and so may in fact be negatively affected to some degree by human activities, but not to the point of deserting their territory (Gill et al. 2001). Leaving their territory not only leaves the area undefended, but it also increases the likelihood of an aggressive encounter with other cranes. Salt marsh habitat on Blackjack Peninsula appears to be saturated with crane territories, which means if one pair leaves its territory the pair will inevitably be encroaching on another pairs' territory, increasing the chance of an agonistic encounter. Territorial cranes may be forced to habituate to human stimuli, as the other option is leaving their territory, which requires greater amounts of energy and may expose the family to an aggressive encounter.

A third potential explanation was that food availability may influence the behavioral response exhibited by a family. In Mar-Apr, when stimulus frequency was the greatest, food availability in the marsh may also have been at a very low level (see Chapter III). Territorial cranes may have been less affected by human stimuli at this time, as the starvation risk outweighed the danger perceived from a human activity (Stillman & Goss-Custard 2002). In other words, continued foraging would be more important for cranes, rather than expending valuable energy in reacting to a human activity.

CHAPTER V

CONCLUSIONS

Behavior of whooping cranes on their wintering territories consisted primarily of foraging, standing in alert posture, preening and resting, and in movement. The majority of time was spent foraging, indicating the importance of this activity for wintering cranes. As a result, temporal and spatial changes in foraging behavior are important in understanding habitat needs for the species. The study of spatial and temporal use of territories indicated that territorial defense early in the wintering season was an important activity. Movement, which includes both walking and flying, was highest for most families during Nov-Dec. Flight behavior was highest in Nov-Dec, primarily associated with territorial defense. Aside from flight, movement may also have been higher during Nov-Dec as cranes traveled between food resources; for example, cranes may have spent more time walking between vegetated areas in search of wolfberry fruits. Food availability may influence the temporal use of the territory, as cranes shift from one food item to another as availability and ease of capture changes. Based on increased movement velocity in Mar-Apr, food availability may be significantly reduced late in the winter season. Pre-migratory unrest may contribute to the increased movement velocity; however, the proportion of time spent in flight did not greatly increase during this time (see Chapter II, Fig. 3). Flight behavior is a typical behavior exhibited by cranes prior to migration (T. Stehn, pers. comm.).

The potential impact of human activities on foraging behavior is important to consider, as human stimulus frequency was significantly greater in Mar-Apr than at other times of the winter. In several instances, cranes exhibited a response to human stimuli. Two families reduced foraging during high intensity stimuli during specific months. One family increased movement in Mar-Apr when more than 5 stimuli occurred in a 30-min observation session, while another family decreased alert behavior and increased foraging as the number of stimuli increased. While the results showed that most cranes did not respond to typical human activities, during winters when food availability is below average, higher frequencies and intensities of stimuli could act as an additional stressor to cranes.

Assuming that the 5 pairs of cranes studied are representative of all cranes on Blackjack Peninsula, I do not believe current levels of human activity to be a major threat to the territorial cranes on Blackjack Peninsula, given the current food resource availability and environmental factors. The typical activities that occurred in close proximity to crane territories, such as motor boats, barges, airplanes or helicopters, and tourboats, did not result in a negative response on the part of most territorial families. The LS family did exhibit negative responses in several cases, yet the reproductive success of LS pair is consistently high. It is difficult to link the effects of human activities on wintering grounds to reproductive success, but based on the consistently high reproductive success of the LS pair, it does not appear that human activities are negatively affecting the pair to a great degree. Increased environmental stressors, such

as a reduction in food availability, could change these conclusions, and lead to increased sensitivity to human activity.

The smaller size of territories on Blackjack Peninsula makes them an interesting area for future studies. Flight was most commonly associated with territorial defense, which may be higher on Blackjack Peninsula, due to the higher density of crane pairs. A comparative study of interactions between neighboring whooping cranes on Blackjack Peninsula and an area with lower densities (i.e. Matagorda Island) would be beneficial in estimating the amount of energy expended in territorial defense. Further examination of landscape characteristics of territories would also be useful in determining the carrying capacity of the current wintering range, and the suitability of surrounding salt marshes for future expansion of the population.

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APPENDIX A

DEFINITIONS OF METRICS USED IN SPATIAL ANALYSIS

FRAGSTATS documentation obtained from: http://www.umass.edu/landeco/research/
fragstats/documents/Metrics/Metrics%20TOC.htm

CLASS METRICS

Largest Patch Index (LPI):

$$LPI = \frac{\max_{j=1}^{n}(a_{ij})}{A}(100)$$

a_{ij} = area (m^2) of patch ij.   A = total landscape area (m^2).

Description: LPI equals the area (m^2) of the largest patch of the corresponding
patch type divided by total landscape area (m^2), multiplied by 100 (to convert to
a percentage); in other words, LPI equals the percentage of the landscape
comprised by the largest patch. Note, total landscape area (A) includes any
internal background present.

Units: Percent

Range: 0 < LPI ≤ 100

LPI approaches 0 when the largest patch of the corresponding patch type
is increasingly small. LPI = 100 when the entire landscape consists of a
single patch of the corresponding patch type; that is, when the largest
patch comprises 100% of the landscape.

Comments: Largest patch index at the class level quantifies the percentage of
total landscape area comprised by the largest patch. As such, it is a simple
measure of dominance.

Patch density:

$$PD = \frac{n_i}{A}(10{,}000)(100)$$

n_i = number of patches in the landscape of patch type (class) i. A = total landscape area (m^2).

Description: PD equals the number of patches of the corresponding patch type divided by total landscape area (m^2), multiplied by 10,000 and 100 (to convert to 100 hectares). Note, total landscape area (A) includes any internal background present.

Units: Number per 100 hectares

Range: PD > 0, constrained by cell size.

PD is ultimately constrained by the grain size of the raster image, because the maximum PD is attained when every cell is a separate patch. Therefore, ultimately cell size will determine the maximum number of patches per unit area. However, the maximum density of patches of a single class is attained when every other cell is of that focal class (i.e., in a checker board manner; because adjacent cells of the same class would be in the same patch).

Comments: Patch density is a limited, but fundamental, aspect of landscape pattern. Patch density has the same basic utility as number of patches as an index, except that it expresses number of patches on a per unit area basis that facilitates comparisons among landscapes of varying size. Of course, if total landscape area is held constant, then patch density and number of patches convey the same information. Like number of patches, patch density often has limited interpretive value by itself because it conveys no information about the sizes and spatial distribution of patches. Note that the choice of the 4-neighbor or 8-neighbor rule for delineating patches will have an impact on this metric.

Clumpiness:

$$Given \; G_i = \left(\frac{g_{ii}}{\left(\sum_{k=1}^{m} g_{ik}\right) - min \; e_i} \right)$$

$$CLUMPY = \left[\begin{array}{l} \dfrac{G_i - P_i}{P_i} \; for \; G_i < P_i \, \& \, P_i < .5, \, else \\[2ex] \dfrac{G_i - P_i}{1 - P_i} \end{array} \right]$$

g_{ii} = number of like adjacencies (joins) between pixels of patch type (class) i based on the *double-count* method.

g_{ik} = number of adjacencies (joins) between pixels of patch types (classes) i and k based on the *double-count* method.

min-e_i = minimum perimeter (in number of cell surfaces) of patch type (class) i for a maximally clumped class.

P_i = proportion of the landscape occupied by patch type (class) i.

Description: CLUMPY equals the proportional deviation of the proportion of like adjacencies involving the corresponding class from that expected under a spatially random distribution. If the proportion of like adjacencies (G_i) is less than the proportion of the landscape comprised of the focal class (P_i) and $P_i <$ 0.5, then CLUMPY equals G_i minus P_i, divided by P_i; else, CLUMPY equals G_i minus P_i, divided by 1 minus P_i. Note, it can be shown that G_i equals 1 when the patch type is maximally clumped, but this requires adjustment for the perimeter of the class. If a_i is the area of class i (in terms of number of cells) and n is the side of a largest integer square smaller than a_i, and m = a_i - n^2, then the minimum perimeter of class i (i.e., when it is maximally clumped), min-e_i, will take one of the three forms (Milne 1991, Bogaert et al. 2000):

min-e_i = 4n, when m = 0, or

min-e_i = 4n + 2, when $n^2 < a_i \leq n(1+n)$, or

min-e_i = 4n + 4, when $a_i > n(1+n)$.

Note, g_{ii} in the numerator includes only internal like adjacencies; like adjacencies involving cells in the border are not included. The sum of g_{ik} in the denominator

includes all adjacencies involving the focal class, including adjacencies involving background and all adjacencies involving the landscape boundary, regardless of whether a border is present or not. Cell adjacencies are tallied using the *double-count* method in which pixel order is preserved. Note, P_i is based on the total landscape area (A) including any internal background present.

Units: None

Range: $-1 \leq CLUMPY \leq 1$

Given any P_i, CLUMPY equals -1 when the focal patch type is maximally disaggregated; CLUMPY equals 0 when the focal patch type is distributed randomly, and approaches 1 when the patch type is maximally aggregated. Note, CLUMPY is undefined and reported as N/A in the output files when the class consists either of a single cell, comprises all but 1 cell, or comprises the entire landscape, because it is impossible to distinguish between clumped, random and dispersed distributions in these cases.

Comments: Clumpiness index is calculated from the adjacency matrix, which shows the frequency with which different pairs of patch types (including like adjacencies between the same patch type) appear side-by-side on the map. Clumpiness is scaled to account for the fact that the proportion of like adjacencies (G_i) will equal P_i for a completely random distribution (see previous discussion). The formula is contingent upon G_i and P_i because the minimum value of G_i has two forms which depend on P_i. Specifically, when $P_i \leq 0.5$, $G_i = 0$ when the class is maximally disaggregated (i.e., subdivided into one cell patches) and is 1 when the class is maximally clumped. However, when $P_i \geq 0.5$, $G_i = 2P_i$ -1 when the class is maximally disaggregated and approaches 1 when the class is maximally clumped.

LANDSCAPE METRICS

Edge density:

$$ED = \frac{E}{A}(10,000)$$

E = total length (m) of edge in landscape. A = total landscape area (m^2).

Description: ED equals the sum of the lengths (m) of all edge segments in the landscape, divided by the total landscape area (m^2), multiplied by 10,000 (to

convert to hectares). If a landscape border is present, ED includes landscape boundary segments representing 'true' edge only (i.e., abutting patches of different classes). If a landscape border is absent, ED includes a user-specified proportion of the landscape boundary. Regardless of whether a landscape border is present or not, ED includes a user-specified proportion of internal background edge. Note, total landscape area (A) includes any internal background present.

Units: Meters per hectare

Range: ED ≥ 0, without limit.

ED = 0 when there is no edge in the landscape; that is, when the entire landscape and landscape border, if present, consists of a single patch and the user specifies that none of the landscape boundary and background edge be treated as edge.

Comments: Edge density has the same utility and limitations as Total Edge (see Total Edge description), except that edge density reports edge length on a per unit area basis that facilitates comparison among landscapes of varying size.

Landscape Shape Index (LSI):

$$LSI = \frac{E}{min\ E}$$

E = total length of edge in landscape in terms of number of cell surfaces; includes all landscape boundary and background edge segments.

min E = minimum total length of edge in landscape in terms of number of cell surfaces (see below).

Description: LSI equals the total length of edge in the landscape, given in number of cell surfaces, divided by the minimum total length of edge possible, also given in number of cell surfaces, which is achieved when the landscape consists of a single patch. If A is the landscape area, including all internal background (in terms of number of cells), and n is the side of the largest integer square smaller than A (denoted $int\ \sqrt{A}$) and m = A - n^2, then the minimum edge

or perimeter of the landscape, min-E, will take one of the three forms (Milne 1991, Bogaert et al. 2000):

min-E = 4n, when m = 0, or

min-E = 4n + 2, when $n^2 < A \leq n(1+n)$, or

min-E = 4n + 4, when A > n(1+n).

Units: None

Range: LSI ≥ 1, without limit.

LSI = 1 when the landscape consists of a single square (or almost square) patch; LSI increases without limit as landscape shape becomes more irregular and/or as the length of edge within the landscape increases.

Comments: Landscape shape index provides a standardized measure of total edge or edge density that adjusts for the size of the landscape. Because it is standardized, it has a direct interpretation, in contrast to total edge, for example, that is only meaningful relative to the size of the landscape. LSI can also be interpreted as a measure of patch aggregation or disaggregation, similar to the class-level interpretation. Specifically, as LSI increases, the patches become increasingly disaggregated.
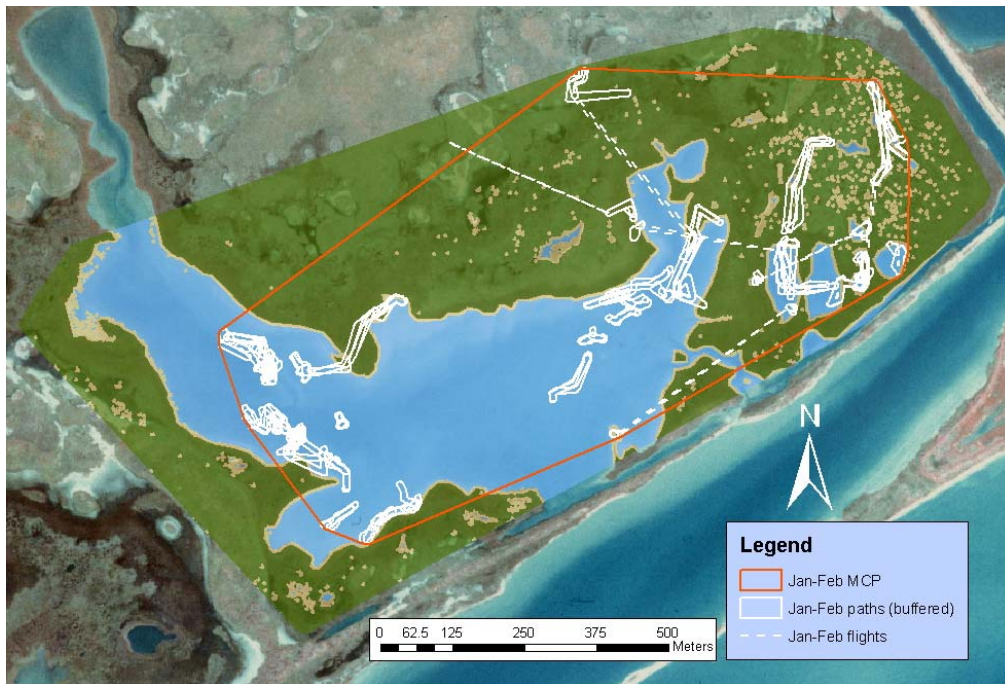
APPENDIX B

MOVEMENT PATHS AT EACH TERRITORY THROUGHOUT WINTER
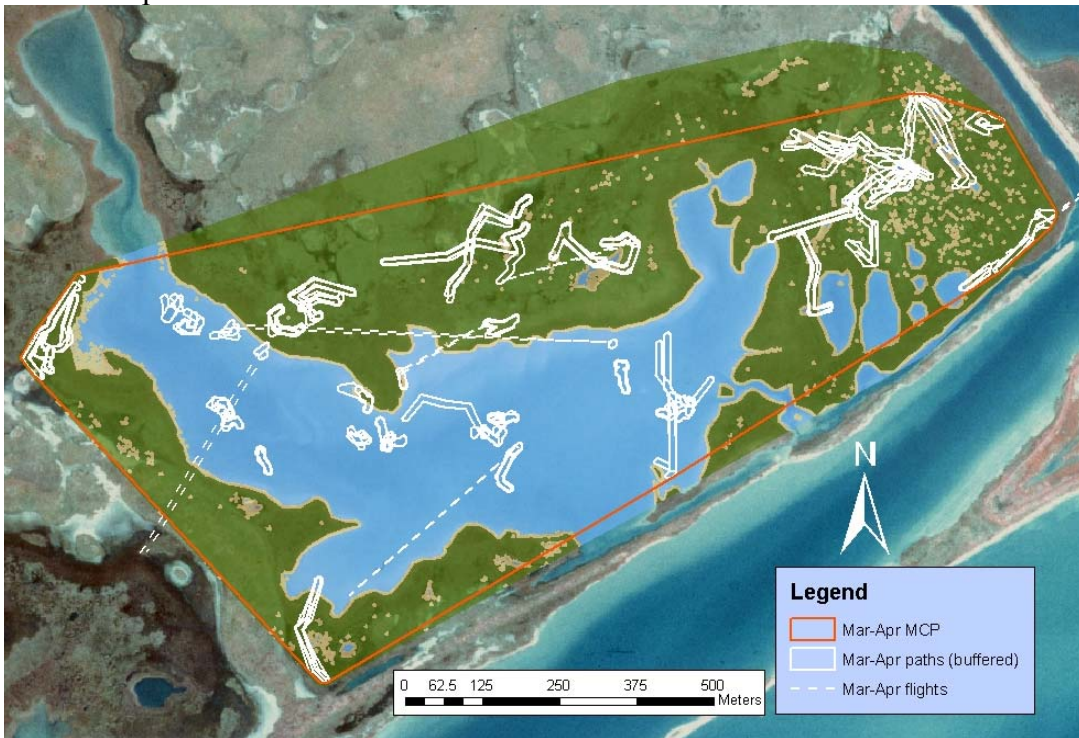
BR Nov-Dec:
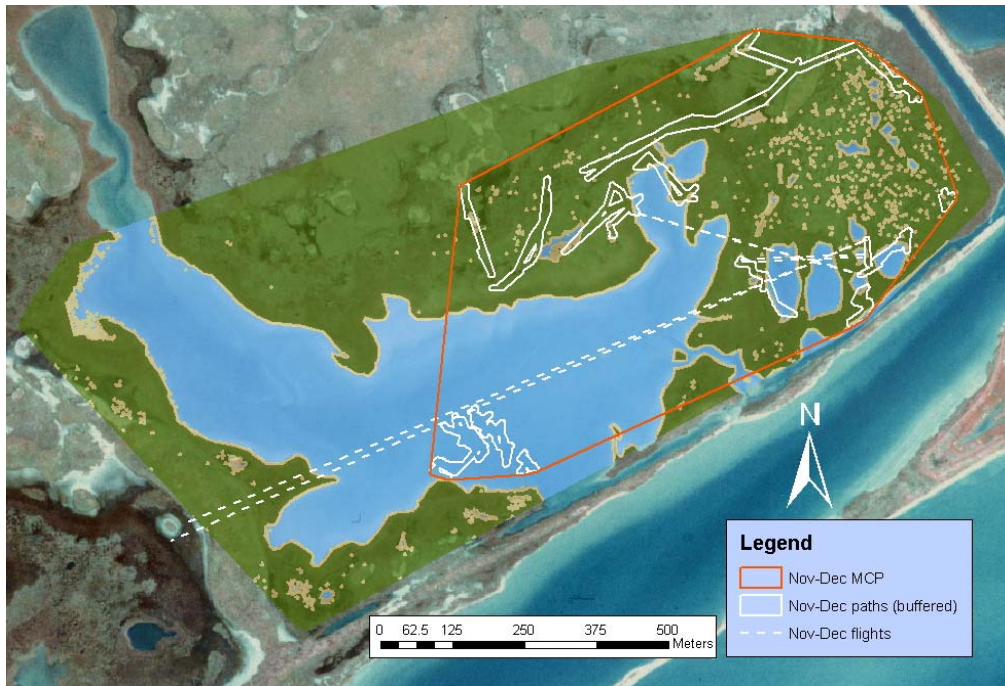
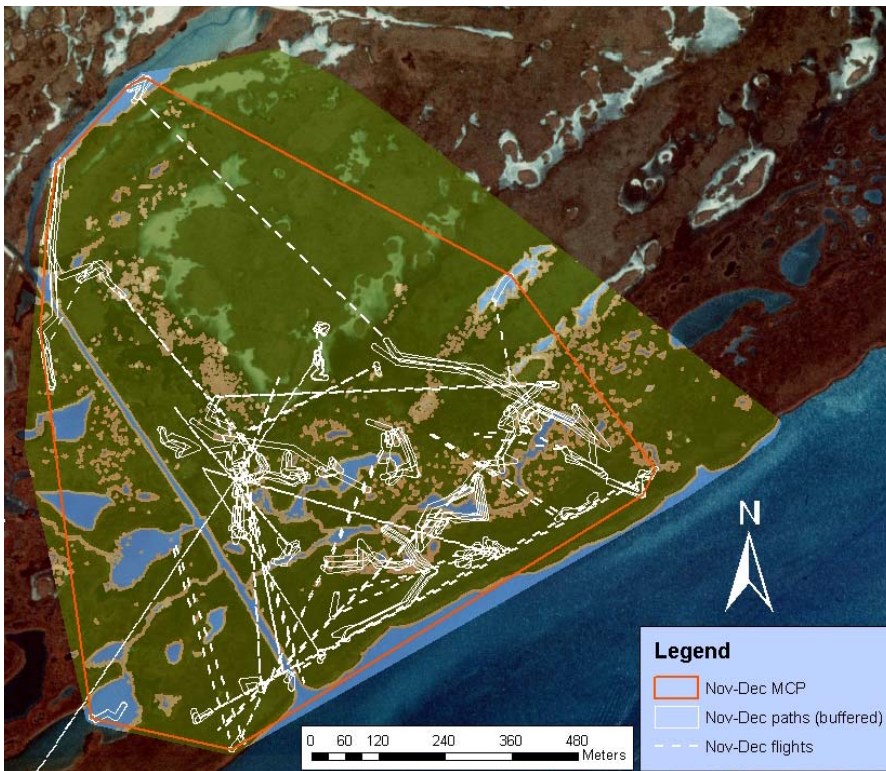

BR Jan-Feb:

BR Mar-Apr:

PC Nov-Dec:

PC Jan-Feb:

PC Mar-Apr:

PL Nov-Dec:

PL Jan-Feb:

PL Mar-Apr:

LS Nov-Dec:
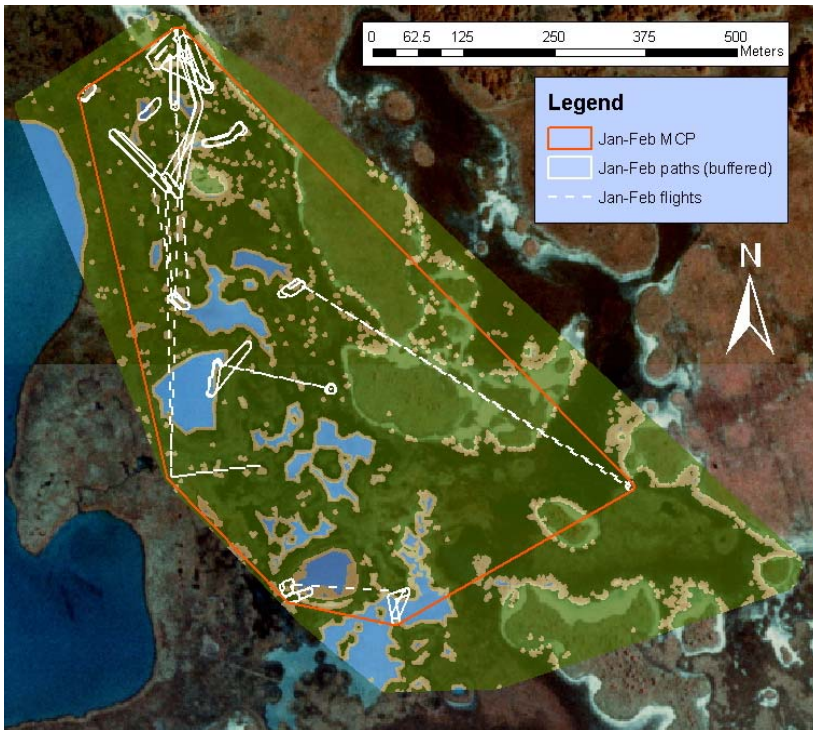
LS Jan-Feb:

LS Mar-Apr:

BJ Jan-Feb:

BJ Mar-Apr:

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