AN INVESTIGATION INTO THE FORAGING ECOLOGY AND CAUSES OF CHICK MORTALITY OF THE NESTING WHOOPING CRANE (*Grus americana*) IN WOOD BUFFALO NATIONAL PARK

by

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ABSTRACT

Twenty-two whooping crane (*Grus americana*) pairs with 2 young were monitored in Wood Buffalo National Park (WBNP) between 1997-1999 to identify causes of chick mortality. The family groups were monitored form the ground, air, and with the aid of radio telemetry. Transmitters were attached to 18 chicks: 5 (28%) fledged, 5 (28%) succumbed to cumulative effects (head trauma, stress, exposure, and/or infection, 4 (22%) were lost to unknown causes, 2 (11%) were taken by foxes (*Vulpes vulpes*), 1 (5.5%) was lost to raven (*Corvus corax*) predation, and 1 (5.5%) died of pneumonia. Of the 22 pairs monitored, 16 young fledged. Of these, 2 (13%) were the younger sibling.

One hundred and forty eight aerial surveys were conducted over the three years to determine the habitat use patterns and foraging ecology of whooping crane families. In addition, 94 ponds were sampled where the whooping cranes were observed feeding in and 94 randomly selected ponds were sampled. The ponds were sampled for fish, invertebrates, water depths, pH, dissolved oxygen, conductivity, salinity and emergent vegetation. It was found that whooping cranes do not feed randomly across their nesting pond complex but are found in ponds that are deeper, colder, closer to creeks, larger, and contain more emergent vegetation than randomly selected ponds. Whooping crane's diet in WBNP was found to be varied and consisted of fish, dragon fly nymphs, diving beetles, snails, frogs and water-milfoil and pond weed. Whooping crane family groups home ranges using the minimum convex polygon method was 3.51 km^2 (SE = 0.6) and ranged in size from 0.57 km^2 to 10.21 km^2.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. GENERAL INTRODUCTION

Introduction……1
Background……2
  Chick Mortality……2
    Research Questions……2
  Habitat Use……3
    Research Question……4
  Diet……4
    Research Question……4
  Home Range……4
    Research Question……5
Outline……5
Permits……5
References Cited……6

Chapter 2. WHOOPING CRANE CHICK MORTALITY

Introduction……12
Study Area……13
  Climate……13
  Physiography and Terrain……13
  Soils……14
  Vegetation……15
Objectives……15
  Brood Rearing Strategies……15
Methods……16
Results……19
  Sibling Aggression……26
  Chick Mobility……27
  Abandonment……27
  Family Movements……28
  Distance from Nests……32
  Adult Behavior with young……32
Discussion……33
  Asynchronous Laying/Incubation/Hatching……34
  Brood Rearing Strategies……35
  Predators and Scavengers……41
  Precipitation……44
  Abandonment……46
  Evaluation of Researcher Handling Impacts……47

- Conclusions … 49
- References Cited … 51

Chapter 3. DIET OF WHOOPING CRANE CHICKS

- Introduction …60
- Study area …60
- Objectives …60
- Methods …61
- Results …62
  - Fourth order habitat selection…65
  - Food Deliveries by adults…66
  - Feeding rate …67
  - Chick necropsies …68
- Discussion …69
- Conclusions …69
- References Cited …70

Chapter 4. HABITAT USE PATTERNS, FORAGING ECOLOGY AND DIET OF ADULT WHOOPING CRANES

- Introduction…71
- Objectives…73
    - Research questions …73
- Study Area…73
- Methods …73
  - Habitat use and foraging ecology …74
    - Diet items …75
    - Feeding trials …76
  - Pond sampling …76
  - Statistical analysis …78
  - Nesting pairs…78
- Results…79
  - Habitat use and foraging ecology …79
    - Third order habitat selection …80
      - Activity of whooping cranes…96
      - Feeding observations…99
    - Fourth order habitat selection…110
      - Ground observations…113
      - Feeding trials…113
    - Pond Sampling…115
      - Emergent vegetation…117
      - Fish …117
      - Distance to creeks…122
      - Core nesting area vs periphery areas …122
- Discussion…126
  - Foraging ecology…126

Third order habitat selection…………………………………………………..…127
Fourth order habitat selection…………………………………………………...131
Energetics ………………………………………………………………………134
Initial Activity ………………………………………………………………….135
Core areas vs periphery areas..……………………………………………….137
Pond sampling …………………………………………………………………138
Emergent vegetation ………………………………………………………141
Fish ……………………………………………………………………………..141
Nesting habitat……………………………………………………………………..143
Wintering grounds…………………………………………………………………144
Migration habitat ……………………………………………………………….146
Conclusions……………………………………………………………………………..146
References Cited………………………………………………………………………..148

Chapter 5. HOME RANGES AND MOVMENTS OF WHOOPING CRANES

Introduction ……………………………………………………………………..…157
Study area………………………………………………………………………..…157
Objectives…..……………………………………………………………………..157
Research Question ……………………………………………………..…157
Methods …………………………………………………………………………..157
Home ranges……………………………………………………………158
Daily movements ………………………………………………………159
Results ……………………………………………………………………………159
Home ranges……………………………………………………………159
Daily movements………………………………………………………….178
Discussion………………..………………………………………………………..179
Second order habitat selection………………………………………………….180
Home range.……………………………………………………………180
Daily movements……………………………………………………….182
Conclusions………………………………………………………………………..183
References Cited…………………………………………………………………..183

Chapter 6. CONCLUSIONS AND RECOMMENDATIONS

Chick Mortality ………………………………………………………………..187
Habitat selection and use…………………………………………………………189
Second order habitat selection………………………………..……………..189
Third order habitat selection…………………………………………………189
Fourth order habitat selection………………………………………………..189
Management implications – Recommendations …………………………………190
Chick Mortality/Survival ……………………………………………………190
Habitat protection ……………………………………………………………….190
Water monitoring………………………………………………………………….191

References Cited ……………………………………………………………192

APPENDICES……………………………………………………………………………193

LIST OF TABLES

Table 2-1. Suspected fates of radio tagged whooping crane chicks, WBNP 1998-1999………..……………………………………… 24

Table 2-2. Weights of whooping crane chicks handles, WBNP, 1997-1999…. .25

Table 2-3. Daily movements of whooping cranes with two chicks, 1997-1999……………………………………………………………29

Table 2-4. Minimum daily movements of whooping crane with chicks during the month of June……………………….………….30

Table 2-5. Adult whooping crane behavior with young …..…………………….32

Table 3-1. Chronology of events and hours of observation for each nest……….65

Table 3-2. Diet items consumed by whooping crane chicks ……………………66

Table 3-3. Number of food deliveries by each adult ……………………………66

Table 4-1. Whooping crane nesting pairs intensively monitored ……………… 79

Table 4-2. Number of aerial surveys conducted during the summer months, 1997-1999……………………………………………………………80

Table 4-3. Number of whooping cranes observed in different habitats during the summer months of 1997, in WBNP………………………82

Table 4-4. Number of whooping cranes observed in different habitats during the summer months of 1998, in WBNP………………………83

Table 4-5. Number of whooping cranes observed in different habitats during the summer months of 1999, in WBNP………………………84

Table 4-6. Habitat use of individual whooping crane pairs.…………………… 86

Table 4-7. Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1997………………………………….88

Table 4-8. Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1998………………………………….88

Table 4-9. Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1999………………………………….89

Table 4-10. Emergent vegetation habitat use by the individual whooping crane pairs ……………………………………………………………….91

Table 4-11. Number of whooping cranes observed ≤ 5 m from three types of emergent vegetation in WBNP 1997-1999 ………………………….92

Table 4-12. Number of observations of whooping cranes on ridges in WBNP 1997-1999…………………………………………………………93

Table 4-13. Number of whooping cranes observed in different sizes (diameter in m) of open water habitats in WBNP during 1997……..94

Table 4-14. Number of whooping cranes observed in different sizes (diameter in m) of open water habitats in WBNP during 1998……..94

Table 4-15. Number of whooping cranes observed in different sizes (diameter in m) of open water habitats in WBNP during 1999…..…..95

Table 4-16. Initial activity of whooping cranes in ponds, 1997-1999……………95

Table 4-17. Initial activity of individual whooping crane pairs in ponds, 1997-1999…………………………………………………………96

Table 4-18. Initial activity of whooping cranes on ridges/islands ……………….97

Table 4-19. Initial activity of whooping cranes in ponds by month, 1997 …….…98

Table 4-20. Initial activity of whooping cranes in ponds by month, 1998 …….…98

Table 4-21. Initial activity of whooping cranes in ponds by month, 1999 ………99

Table 4-22. Habitat where whooping cranes were observed feeding in WBNP in 1997……………………………………….…………...99

Table 4-23. Habitat where whooping cranes were observed feeding in WBNP in 1998…..…………………………………………….100

Table 4-24. Habitat where whooping cranes were observed feeding in WBNP in 1999 ………………………………………………101

Table 4-25. Number of observations of whooping cranes feeding in emergent vegetation in WBNP 1997-1999..…………………………………..103

Table 4-26. Number of whooping cranes observed feeding ≤ 5m from emergent vegetation in WBNP 1997-1999……………………………………104

Table 4-27. Habitat where individual pairs of whooping cranes were observed feeding……………………………………………………………105

Table 4-28. Type of emergent vegetation habitat used for feeding by Individual pairs of whooping cranes………………………………..106

Table 4-29. Color of ponds where the whooping cranes were feeding …………107

Table 4-30. Approximate water depths where the whooping cranes were feeding………………………………………………………..108

Table 4-31. Approximate water depths where individual pairs of whooping cranes were observed feeding……. ………………………………………109

Table 4-32. Summary of food items identified in whooping crane fecals..…..…110

Table 4-33. Seeds found in whooping crane fecals, 1996-1999 ………………..111

Table 4-34. Insect parts in whooping crane fecals, 1996-1999…………………111

Table 4-35. Comparison of insect parts in whooping crane fecals, between 1996 and 1999…………………………………………….112

Table 4-36. Feeding trials at the Calgary Zoo, 1998………….……………..…114

Table 4-37. Environmental variables sampled in random and feeding ponds……………………………………………………Appendix I

Table 4-38. Fish, amphibians, and invertebrates caught in random and feeding ponds with minnow traps…………………………Appendix I

Table 4-39. Fish, amphibians, and invertebrates caught in random and feeding ponds with invertebrate traps……………………..Appendix I

Table 4-40. Snails caught in random and feeding ponds ………………Appendix I

Table 4-41. Water depths of ponds without emergent vegetation and ponds with emergent vegetation………………………Appendix I

Table 4-42. Characteristics of ponds where fish were not caught and where fish were caught ……………………………….Appendix I

Table 4-43. Number of amphibians and invertebrates caught in ponds where fish were not caught, and where fish were caught using minnow traps ……………………………………………Appendix I

Table 4-44. Number of amphibians and invertebrates caught in ponds where fish were not caught, and where fish were caught using invertebrate traps……………………………………………Appendix I

Table 4-45. Comparison of amphibians and invertebrates caught in ponds where fish were caught and in ponds where fish were not caught using both minnow and invertebrate traps..Appendix I

Table 4-46. Fish caught per trap night…..……….………………………..121

Table 4-47. Invertebrates caught per trap night…………………………………121

Table 4-48. Comparison of productivity of ponds with number of young produced per nesting pair...…………………………………………123

Table 4-49. Percentage of fledged young per nesting pair in periphery and core nesting areas in WBNP, 1997-1999………………………124

Table 4-50. Water levels and reproductive success as measured in fledged young/nest……………………………………………………….125

Table 4-51. Fish caught in whooping crane territories of pairs monitored for 3 consecutive years…………………………………………………125

Table 5-1. Number of aerial surveys conducted during the summer months, 1997-1999 ……………………………………………………….158

Table 5-2. Nesting pairs monitored…………………………………………….159

Table 5-3. Home ranges of nesting whooping cranes in WBNP using the Fixed kernel method (50% UD and 95% UD), >30 locations……160

Table 5-4. Home ranges of nesting whooping cranes in WBNP using the Minimum Convex Polygon Method (100%) ………………..……161

Table 5-5. Comparison by year using the Minimum Convex Polygon Method (100%)………………………………………………….162

Table 5-6. Minimum Convex Polygon Method (100%) for June……………..163

Table 5-7. Minimum Convex Polygon Method (100%) for July……………...163

Table 5-8. Minimum Convex Polygon Method (100%) for August…………..164

Table 5-9. Daily movements during the summer months for all nesting Pairs observed, 1997-1999 ………………………………………..179

LIST OF FIGURES

Figure 2-1. Study Area ………………………………………………………… 59

Figure 3-1. Number of feedings/hour ……………………………………….. 68

Figure 4-1. Habitat use by month …………………………………………….85

Figure 4-2. Emergent vegetation use by year, 1997-1999……………………90

Figure 4-3. Habitat used for feeding, 1997-1999 …………………………….102

Figure 4-4. Relative abundance of amphibian and major invertebrate taxa in 94 random and 94 feeding ponds ……………………….116

Figure 4-5. Pond variables where fish were caught and where no fish were caught …………………………………………………….119

Figure 4-6. Relative abundance of amphibians and major invertebrate taxa in 85 ponds with fish and 103 ponds where no fish were caught ……………………………..………………….120

Figure 5-1. Nest Pair A, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….165

Figure 5-2. Nest Pair A99, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….166

Figure 5-3. Nest Pair B, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….167

Figure 5-4. Nest Pair C, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….168

Figure 5-5. Nest Pair D, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….169

Figure 5-6. Nest Pair E, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….170

Figure 5-7. Nest Pair F, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….171

Figure 5-8. Nest Pair G, home range, 50% and 95% utilization distribution and MCP 100% ………………………………………………….172

Figure 5-9. Nest Pair H, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….173

Figure 5-10. Nest Pair I, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….174

Figure 5-11. Nest Pair J, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….175

Figure 5-12. Nest Pair K, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….176

Figure 5-13. Nest Pair L, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….177

Figure 5-14. Nest Pair M, home range, 50% and 95% utilization distribution and MCP 100% ……………………………………………….178

Chapter 1

GENERAL INTRODUCTION

Introduction

Wetlands in and around Wood Buffalo National Park (WBNP) represent the only continuously inhabited breeding grounds of the endangered Whooping Crane (*Grus americana*). There were an estimated 1400 whooping cranes between 1860-1870 distributed throughout the wetlands of North America (Allen 1952). Agricultural expansion and the associated draining of wetlands, and increased hunting reduced the population to a low of 16 individuals in 1941 (Allen 1952). Nest sites were first observed in WBNP in 1954 when five pairs were located (Fuller 1955). The current (2007) WBNP population numbers 65 nesting pairs and approximately 235 individuals. This population remains the only self-sustaining wild flock of whooping cranes in the world.

Many factors continue to threaten the long term survival of this population. On their wintering grounds at the Aransas National Wildlife Refuge in Texas, whooping cranes and their habitat are at threat from accidental petroleum and chemical spills, and hurricanes (U.S. Fish and Wildlife Service 1994). Additional threats to the population include predation on the nesting grounds, collision with power lines during their 4000 km migration and accidental shootings (U.S. Fish and Wildlife Service 1994).

The Canadian Whooping Crane Recovery Plan outlined a management program which identified priority issues (Edwards et al. 1994). These priorities included the following: to determine the availability of suitable habitat for breeding, to identify characteristics of occupied and unoccupied habitat through the sampling of potential food resources in whooping crane feeding areas, and to determine the size of areas used by individual pairs to assist in assessing the carrying capacity of the area (Edwards et al. 1994). Another priority identified in the recovery plan is to determine the cause of egg loss and chick mortality (Edwards et al. 1994).

Annual nest distribution, hatching success and juvenile survivorship surveys have occurred on the nesting grounds in WBNP since 1967. However, limited information existed with regard to potential limiting factors on the nesting whooping crane population such as knowledge of food items in their diet, distribution of these items, or causes of mortality of their young. The main objectives of this three year (1997-1999) study were: to identify causes of chick mortality on their nesting grounds; determine habitat use patterns; to identify the main food items in the whooping cranes diet; and to determine home ranges and territories.

Background

Chick Mortality

Whooping cranes generally lay a clutch of two eggs (Kuyt 1995) but rarely arrive on their wintering grounds with two young. Chapter 2 identifies causes of whooping crane chick mortality and compares whooping cranes' rearing strategies with various hypothesis of brood reduction, namely; the Resource Tracking, Replacement Offspring and Sibling Facilitation Hypotheses. Understanding of whooping cranes brood rearing strategies is essential to understand population fluctuations and trends.

Research Questions

Why do whooping cranes lay two eggs but normally only raise one young?

What type of chick rearing strategy is used by whooping cranes?

Habitat Use

Of the historical whooping crane nesting areas described by Allen (1952), aspen parkland was the most common general habitat area, with specific nesting sites found in sloughs and shallow lakes (Allen 1952).

A whooping crane nesting habitat study in WBNP was conducted in 1996 found at a scale of 300 m^2 around the nest, whooping cranes selected for a particular habitat rather than nesting randomly on the landscape. Nest sites were characterized as diatom ponds with shorelines of common bulrush (*Scirpus validus*). Potential indicators of whooping crane nesting habitat were found to be: common bulrush; creeping spike-rush (*Eleocharis palustris*); and small bladderwort (*Utricularia minor*). Whooping cranes also appeared to select sites with large concealment distances (i.e. visually open habitat), large amounts of open water, small amounts of terrestrial vegetation and relatively short distances from the nest to water (Timoney 1997).

Second and third order habitat selection (Johnson 1980) of whooping cranes was evaluated in Chapter 4. In order to evaluate and assess the range/habitat potential of their current nesting area and determine the feasibility of reintroduction sites for whooping cranes, understanding of their second and third order habitat selection is fundamental.

Research Question

What habitat characteristics occur in whooping cranes second and third order habitat selection?

Diet

Fourth order habitat selection (Johnson 1980) of young and adult whooping cranes was evaluated in Chapters 3 and 4 respectively. Determining what items make up the whooping cranes diet is essential in assessing annual fluctuations in the population, understanding future range expansions and evaluating potential reintroduction sites.

Research Question

What are the main food items in the whooping crane's summer diet?

Home Range

Kuyt (1993) estimated home ranges for isolated breeding pairs in WBNP to range from 2.0 - 18.9 km^2. In areas of higher density the range was 3.2 to 4.2 km^2 and average home ranges of 13 pairs in the core nesting areas (Sass, Klewi, Sass-Klewi) was 4.1 km^2.

Size of territories and home ranges of nesting whooping cranes can be found in Chapter 5. Determining home range and territory size required by a pair of nesting whooping cranes is necessary to know how many pairs can coexist and be supported in an area. It also allows for predictions of range expansion and plan on how much habitat is required for reintroduction purposes.

Research Question

What is the area utilized by nesting whooping cranes?

Outline

Descriptive methods are used to summarize the observation data, to identify patterns and to generate hypotheses while inferential methods are used to test relationships statistically by accepting or rejecting a hypothesis.

In Chapter two, whooping crane chick mortality, descriptive methods were primarily used as a result of the small sample sizes. In Chapters three and four, habitat selection and usage was analyzed with analysis of variance and comparisons made between feeding (used) and random (non-used) ponds. In Chapter five home range boundaries was produced with the Home Range Extension for Arc View 3.x. SigmaStat (2.0) (SPSS 1997) statistical software was used for statistical analysis. Unless otherwise stated the level of alpha used for all statistical tests was 0.05.

Permits

The following permits were obtained for the research undertaken. Animal Care (97-34D) from the University of Alberta, Environmental Assessment Review Process Registry 97-1014, Research Permit Collection 98-1014, Canadian Wildlife Service Permit for Scientific Take or Disturbance of Migratory Birds NWT-SCI-98-04.

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Chapter 2

WHOOPING CRANE CHICK MORTALITY

Introduction

Wetlands in and around Wood Buffalo National Park (WBNP) represent the only continually inhabited breeding grounds of the endangered whooping crane (*Grus americana*) in the world. Whooping crane nesting sites were first observed in WBNP in 1954 when five pairs were located (Fuller 1955). The current (2007) population numbers close to 235 individuals.

The incidence of two-egg clutches of whooping cranes is over 90% (Kuyt 1995) and hatching success is between 70-80% (Kuyt 1996). Until 2006, there were only two whooping crane families that arrived on their wintering grounds with both of their young over the previous thirty-five years (it occurred in 1997 and 2003, in 2006 there were 7 families that arrived on their wintering grounds with both young). However, between 1967 and 1996, 453 eggs were removed (from nests containing two eggs) from the nesting population for population management initiatives. The exact impact of the egg collection program on the WBNP population is unknown, but has been debated by (Bergeson et al. 2001, Cannon et al. 2001, Ellis and Gee 2001, Boyce et al. 2005).

Predation on whooping crane eggs is minimal and hatching success of eggs left in nests during the egg collection period averaged 79% (Kuyt 1981). Most of the chicks that went missing did so in their first two weeks following hatching (Kuyt 1981) but little information existed with regards to the causes of whooping crane's failure to hatch eggs and chick mortality following hatching.

The purpose of this study was to gain information on the causes of chick mortality and determine the brood rearing strategy used by whooping cranes. This information will aid resource managers in understanding the variability of chick production in WBNP and in future re-introduction efforts.

Study Area

Climate

The study area is located in the northeast corner (59^0 45' - $60^0$30'N, and 112^0 45' - 113^0 55' W) of Wood Buffalo National Park (Figure 1-1). Wood Buffalo National Park comprising 44,807 km^2 is located in the subhumid mid-boreal ecoclimatic region of Canada (Ecoregions Working Group 1989). Figure 1-1: Study area map. Follows references cited section.

The annual number of frost-free days (from 1961-1990) averaged between 80-120 (Ecoregions Working Group 1989). Average annual precipitation for the area was 352.9 mm, and the land was usually snow-free by early to mid May and snow-covered by mid-October (Environment Canada 1993).

Physiography and Terrain

Regionally, the area is part of the Great Slave Plain physiographic division (Geological Survey of Canada 1970) and is characterized by till plains, sandplains and carbonate deposits over karst (Airphoto Analysis Associates 1979). Bedrock in the study area is the Middle Devonian Nyarling Formation, consisting of gypsum karst and limestone. The topography is level to depressional (Airphoto Analysis Associates 1979). Most of the area is affected by calcium sulphate groundwater discharge and is part of a groundwater flow system originating in the Caribou Hills, to the southwest (McNaughton1991 Unpublished). The chemistry of springs and ponds is strongly influenced by the dissolution of gypsum. The dominant ions in the water are sulphate, calcium, bicarbonate, and magnesium, with lesser amounts of sodium, potassium and chloride. The ponds in the whooping crane nesting area are neutral to alkaline (McNaughton 1991 Unpublished). Most of the surficial deposits consist of organic terrain (>80%), particularly in the core of the nesting area. Subdued rises of fluted loamy tills dot the area (Airphoto Analysis Associates 1979). Permafrost underlies approximately 30% of the study area (Airphoto Analysis Associates 1979), particularly the palsa and peat plateau landforms.

Thermokarsting of ground ice may be an important process leading to landscape diversity and to the formation of diatom ponds in former peatlands. Due to recent fires most palsa and peat plateaus in the study area do not have a lichen (*Cladonia spp*.) dominated surface; rather they are brownish due to shrub and moss (*Sphagnum spp*.) dominance (Timoney 1997).

Soils

Bog and fen peats are typically mesic in texture; floating mats are fibric near the surface and become mesic with depth; diatom ooze deposits are humic since their predominant constituents are diatoms (including: *Amphora spp*., *Cymbella spp*., *Epithemia spp*., *Gomphonema spp*., *Mastogloia spp*., *Navicula spp*., *Nitzschia spp*., *Rhopalodia spp*.), (Timoney 1997).

Vegetation

A mosaic of diatom ponds, bulrush (*Scirpus validus*) marshes, water sedge meadows (*Carex spp*.), fens, bog-fens, and bogs dominate the wetland complex (Timoney 1997). Fen and bog types may be either shrub dominated with dwarf birch (*Betula glandulosa*), willows (*Salix athabascensis*, *S.candida*, *S.myrtillifolia, S. planifolia)*, sweet gale (*Myrica gale*), labrador tea (*Ledum groenlandicum*), or tree dominated, with white spruce (*Picea glauca*), black spruce (*P. mariana*) and tamarack (*Larix laricina*). The thicker peat landforms are typically palsa and peat plateaus, in which thermokarst ponds are common. Upland forests are characterized by closed to open canopy of white spruce, jack pine (*Pinus banksiana*) and poplar (*Populus balsamifera*, *P. tremuloides*) (Timoney 1997).

Objectives

To identify causes of whooping crane chick mortality following hatching in WBNP.

To evaluate and compare whooping cranes' brood rearing strategies with common theories of brood reduction including: the Resource Tracking Hypothesis; the Replacement Offspring Hypothesis; and the Sibling Facilitation Hypothesis.

Brood Rearing Strategies

Resource Tracking Hypothesis: when the whooping crane adults arrive on the nesting grounds in late April many of the ponds are still ice covered and they do not have complete information about whether the summer will be poor, good or adequate with regard to water and food resources. This results in the parents producing the number of young that they could raise if the upcoming summer turned out to be good or above average.

Replacement theory: if there are “extra” or marginal offspring the whooping crane parents have the option of using these to replace core members that may be inadequate, so the second chick serves as a backup or insurance in case something happens to the core member (predation) or allows the parent to select the higher quality young (genetic defect).

Facilitation Theory: the second hatched marginal whooping crane chick provides other services to the core offspring like insulating properties on the nest during the first critical week following hatching, essentially the second whooping crane chick helps to keep the first core chick warm.

Methods

In May of 1997, three fixed wing surveys in a Cessna 172 were conducted over the nesting area to determine the number of nests, the location of nests and the onset of incubation. In June, eight nesting pairs with two chicks were selected for aerial monitoring and at least one flight was conducted daily (35 surveys) to observe when their eggs hatched, record daily movements and timing of when chicks went missing. The locations of the families were plotted on overlays on 1:15,840 colour infrared aerial photographs. After a fixed wing flight failed to locate all the chicks, a helicopter (Aerospatiale A-Star or a 206B Jet Ranger) was used to fly out to the last known location of the chick(s) and a ground search was conducted. Two nesting pairs (97-39, 97-6) that had two chicks were visited within a day of the second egg hatching. A helicopter was used to land 300 m away from the nest ponds. The chicks were weighed and marked (with a felt marker) under their wings.

In May of 1998, the number of nests, location of nests and the onset of incubation were determined from five aerial surveys. A plywood blind was transported by helicopter and set up 70 m from a nest site (98-14). The blind's dimensions were; 120 cm by 120 cm in width and 195 cm in height with viewing ports on three sides. At the same time the blind was put into place, the eggs were floated to determine fertility and to get an approximate hatching date. A camp was established 1000 m away from the nest pond and observation sessions in the blind lasted from two-six hrs and continued for 13 days until the family group departed the nest pond. Information was recorded on feeding, and nesting behaviour of the adults and the chicks with the aid of a spotting scope (15 x 60 power) and binoculars (10 x 50 power).

During the first week in June 1998, six nesting pairs that had two chicks were selected for monitoring. A helicopter was used to land 300-400 m away from the family groups. The chicks were weighed, given a physical, and blood samples (800 ul) and swabs (cloaca and trachea) were taken by Dr. R. Cooper (Calgary Zoo). A lightweight (1.45g) transmitter (BD-2G), from Holohil Systems Ltd. was attached to the dorsum of the chicks. The transmitters were attached to the skin of the chicks using a cyanoacrylate glue (Vetbond tissue adhesive) and antennas were glued into the down along the back of the chicks. The transmitters were manufactured with a 15 cm antenna but on smaller chicks (< 200 g) two to four cm were removed from the end of the antenna to avoid overhang. Three transmitters were attached to the larger chick from three separate pairs and three were attached to the smaller chick from three pairs such that only one chick per nesting pair had a transmitter. On three occasions only one chick from a pair of chicks could be located on the ground; in these cases, chick hatching order was estimated by their weight. After the attachment of the transmitters each family group was monitored daily from a fixed wing for 10 consecutive days (10 surveys). The chicks with transmitters were monitored using aerial telemetry; a Telonics (Model TR 2) receiver was used to monitor the transmitter signals. The receiver was connected to two (RA-2A H-Type) Yagi antennae mounted onto the wing struts of a fixed wing aircraft (Cessna 172). A switch box controlled signal input from either or both antennae. When a chick was not located during a monitoring flight a ground search using telemetry ensued at the last known location of the missing chick(s).

In April and May of 1999, 10 aerial surveys were conducted to determine number and location of nests, and the onset of incubation. In late May, three blinds were set up 70 m from three nests (nests: 99-4, 99-5, 99-16). The blinds were identical to the one used in 1998 and were set up in the same manner, with camps being established 800-1000 m away from the nest ponds. The observation sessions began one-two days prior to the eggs hatching and varied from two-five days, until the family groups departed the nest pond. In early June, 12 transmitters were attached to both siblings from six sets of chicks. All 12 chicks were located and weighed. Both chicks in a family group had transmitters attached. The transmitters were the same as in 1998 and were attached to the chicks in the same manner. All transmitters attached to smaller chicks (< 200 g) had four to six cm of the antenna removed. After the attachment of the transmitters, telemetry monitoring occurred at least daily for 15 consecutive days (19 surveys). When a chick was not located during a monitoring flight a ground search using telemetry ensued at the last known location of the missing chick(s).

Results

In 1997, six attempts were made to locate missing chicks on the ground all were unsuccessful. The probability of locating a chick through observations from the air was low due to the thick vegetation and wet terrain. In addition, both chicks from a nesting pair survived longer and the family groups moved over larger distances following hatching than were anticipated. Although missing chicks were not located (including the ones marked), information was gained on the timing of when the chicks went missing, their movements, and their habitat use. Monitored chicks that went missing did so between day 7 and 22 following hatching, and on average went missing 14.3 ($n = 7$, $SE = 2.1$) days after they hatched. The young of one pair (97-23) survived through June. This pair turned out to be the first pair to successfully raise both chicks and arrive on the wintering grounds with two young since 1964.

In 1998, transmitters were attached to six chicks ranging in age (estimated) from 3 to 12 days (Table 1-2). Age was determined by observed hatched dates or estimated from weights at date of capture (Table 2-2). Necropsies were performed by Dr. R.Cooper on two chick carcasses located intact in 1998. One chick, 98-11b (smaller sibling), died from pneumonia (Cooper pers. comm. 1998) and was located along the shoreline of the same pond where it was handled. This particular chick had appeared weak when handled (difficulty keeping head up) the previous day. The adults and remaining sibling were observed 400 m away. The larger sibling's, (98-11a), fate is unknown as pair 98-11 was observed in August without a chick. No primary cause of death could be determined for the other chick carcass located, 98-15b (smaller sibling), although it was dehydrated and had mild head trauma (Cooper pers. comm. 1998). This chick may have been abandoned since it was located on a willow/birch ridge 75 m from where it was handled two days earlier. The adults and remaining sibling were observed 350 m away. The larger sibling, 98-15a, fledged in August. The third mortality, 98-10b (smaller sibling), only the transmitter was located, and it was found in a raven's (*Corvus corax*) roosting perch, 75 m from a raven's nest, approximately two km from where the chick was handled. The larger sibling, 98-10a, fledged in August.

The remaining three transmitters which were attached to the larger siblings either fell off or were pulled off after 5, 6, and 8 days following attachment. At nest 98-40 only one chick (98-40a) could be located and captured on the ground, the following day both chicks were observed with the adults. Chick 98-40a lost its transmitter 5 days following attachment, and 5 days later both chicks from this pair went missing; their fate was unknown. At nest 98-45 only one chick could be located (98-45a) and the following day only chick 98-45a was observed with the adults. Chick 98-45a lost its transmitter 6 days following attachment and was observed to fledge in August. The third larger sibling with a transmitter was chick 98-18a, this chick lost its transmitter 8 days following attachment at which time both chicks were observed with the adults. Three days later only one chick was observed with pair 98-18, and in August this pair did not have a chick. In 1998, monitored chicks that went missing did so between day 4 and 22 following hatching, and on average went missing 9.8 (n = 4, SE = 4.1) days after hatching.

In 1999, 12 transmitters were attached to six sets of chicks, ranging in age from one to eight days (Table 1-2). The day after the transmitters were attached, all the chicks that were handled were observed with the adults except for one, (99-13b), which was 400 m from the adults and remaining sibling. A ground search was conducted later that day and the chick was located alive, it was wet and laying under a small stand of willows on a willow/birch ridge 110 m from where it was handled. The weather was cool (+14 ^{0} C) with light rain. The researcher determined that this chick was abandoned, so the chick was taken, kept over night and then sent to the Calgary Zoo. The previous day when the transmitter was attached to this particular chick, both adults were observed 70 m away from the nest pond with only one young (larger sibling, 99-13a) while the smaller sibling was located by itself only meters from the nest. This smaller chick, 99-13b, which was less than 24 hrs old and weighed 97 g (lightest of any chick handled) was moved and released with its sibling although it was noted at the time that it appeared this chick was being abandoned. Chick 99-13b lived for two additional days in Calgary but died from the cumulative effects of infection and kidney failure (Cooper pers. comm. 1999). The larger sibling, chick 99-13a, lost its transmitter 12 days following attachment and fledged in August.

In 1999, three chick carcasses were located intact and necropsies were performed on them by Dr. R. Cooper. The first chick carcass, 99-7b (smaller sibling), was located floating in wet *Carex spp* .. A primary cause for its death could not be identified, although it was likely from the cumulative effects of mild head trauma, infection and exposure (Cooper pers. comm. 1999). The larger sibling from this brood, 99-7a, lost its transmitter 15 days following attachment, but went missing between the third week in June and the second week in July. The second chick carcass, 99-1b (smaller sibling), had severe head trauma and lost 56 g (23% of its weight when handled) in four days following attachment of the transmitter; it was emaciated and had initial signs of pneumonia. This chick was located on a small island in the center of a pond, while the adults were observed with the remaining (larger) sibling 430 m away. The larger sibling from this pair, 99-1a, lost its transmitter eight days following attachment and was observed to have fledged in August. The third chick carcass, 99-10b (smaller sibling), was located on shore in dry *Carex spp*.. This chick also had mild head trauma and signs of exposure and infection. This particular chick survived for at least one day by itself and appeared to be abandoned as the adults were observed at least 475 m from the chick for two consecutive days prior to locating the chick on the ground. The larger siblings (99-10a), fate was unknown. Two days following the attachment of the transmitter a signal could not be picked up from chick 99-10a and this chick was not observed with the family group. The area was searched extensively from the air however no signal was received. Either a predator/scavenger disabled the transmitter or the transmitter itself failed. The remains of one chick, 99-6a (larger sibling), was located underground in a red squirrel (*Tamiasciurus hudsonicus*) midden. It appeared that a fox (*Vulpes fulva*) (fox scat in area and teeth marks on remains) took the chick to the squirrel midden and then a squirrel took the transmitter and last few remains underground. The smaller sibling from this brood, chick 99-6b, lost its transmitter 14 days following attachment and was observed to have fledged in August. The remains of a second chick, 99-2a (larger sibling), were found along a willow/birch ridge and again fox predation was suspected (tracks and scat in area and teeth marks on remains). The smaller sibling from this brood, chick 99-2b, lost its transmitter seven days following attachment and two days later went missing; as a result, the cause of its demise is unknown. Chicks monitored in 1999 that went missing did so between day 4 and 14 following hatching, and on average went missing 7.6 (n = 7, SE = 1.5) days after hatching (Table 2-1). The mean difference in weights between the siblings was 47.6 g (SE = 7.4) (Table 2-2).

In this study, if a whooping crane chick survived until the end of June (three-four weeks following hatching) it had an 92% chance of fledging and 69% chance of making it to the wintering grounds. The first few weeks of a whooping cranes life is when the highest mortality occurs.

Table 2-1: Suspected fates of radio tagged whooping crane chicks, WBNP, 1998-1999.

	Age (days)			
Chick no.	Transmitter attachment	Transmitter off	At death	Suspected fate
98-10b	3		4	Raven predation
98-11b	5		6	Pneumonia
98-15b	5		7	*Cumulative effects
98-18a	4		8	**Unknown
98-40a	12	5	22	Unknown
98-45a	5	6		Fledged
99-1a	8	12		Fledged
99-1b	6		10	*Cumulative effects
99-2a	5		14	Fox predation
99-2b	3	7	11	Unknown
99-6a	6		8	Fox predation
99-6b	3	14		Fledged
99-7a	5	15		***Unknown
99-7b	3		7	*Cumulative effects
99-10a	2		4	*Unknown
99-10b	4		7	*Cumulative effects
99-13a	3	12		Fledged
99-13b	1			Cumulative effects

Cumulative effects include mild-severe head trauma, exposure and infection (usually signs of pneumonia)
*evidence of mild trauma to the head, chick 99-1b had severe trauma to the head
**chick 98-18a (larger sibling) lost its transmitters eight days following attachment, at that time both chicks were observed, three days later one chick was missing and pair 98-18 did not have a chick in August
***chick observed at end of June but not observed in August

Table 2-2: Weights (grams) of whooping crane chicks handled, WBNP, 1997-1999. (a) indicates older chicks, (b) indicates younger * indicates single chicks located so hatching order was estimated by weight.

Chick no.	Live Weight	Difference Between Siblings	Carcass Weight	Difference Live and Carcass	Sex
97-6a	150	9			Unk
97-6b	141				Unk
97-39a	142	26			Unk
97-39b	116				Unk
98-10a	219	63			Unk
98-10b	156				Unk
98-11a	235	68			Unk
98-11b	167		155	-12	M
*98-15b	161		149	-12	F
98-18a	232	69			M
98-18b	163				F
*98-40a	450				M
*98-45a	230				Unk
99-1a	302	63			Unk
99-1b	239		183	-56	F
99-2a	228	81			Unk
99-2b	147				Unk
99-6a	168	51			Unk
99-6b	117				Unk
99-7a	183	38			Unk
99-7b	145		146	+1	F
99-10a	148	8			Unk
99-10b	140		116	-24	M
99-13a	144	47			Unk
99-13b	97				Unk

Sibling Aggression

The ground observations from the two nest sites that hatched both their eggs in 1999 revealed that there was considerable aggression between the older (larger) and the younger (smaller) sibling . At nest 99-5, two bouts of aggression were observed. In the first bout, the larger sibling pecked the smaller one 93 times in a four minute period and in a second bout the larger sibling pecked the smaller one 60 times over an eight minute period for a total of 150 pecks in 12 minutes or one peck per 4.8 seconds. Four hours later during that observation session, the adults walked 75 m off the nest with the older chick and left the younger chick on the nest. Two hours later a raven circled the nest, landed briefly and flew off with the smaller chick. The adults were agitated, made alarm calls, and paced back and forth but both remained with the older (larger) sibling and did not fly back to the nest in an attempt to fend off the raven. Observations made at nest 99-16, also revealed aggression between the chicks. In one three minute bout the larger chick pecked the smaller one 30 times, although the smaller one also pecked at the older one several times. Out of nine smaller (younger) sibling chicks that were handled while transmitters were attached, four had obvious signs of trauma to the head region. Every one of these chicks perished within four days of handling. The five necropsies conducted on chick carcasses indicated that four had evidence of head trauma. All were the smaller sibling. While it was not possible to observe sibling aggression during the aerial monitoring the researcher observed that the adults rarely kept the chicks separated, as indicated by the fact that only six percent of the observations (n = 188) of family groups with two chicks were of one chick with each adult. The average distance between the chicks was 3.0 m (n = 188, SE = 0.5). Most (70%) of the observations (n = 188) of family groups with two chicks were of the chicks two m or less from one another. The chicks were on average 1.5 m away from an adult (n = 188, SE = .1), while the adults with a chick(s) themselves averaged 17.0 m from one another (n = 188, SE = 2.0).

Chick Mobility

At both blinds situated at nest sites that hatched two eggs, the first chick emerged two days earlier than its younger sibling. During the first 24 hours following hatching, the chicks were unable to take more than three or four steps at a time and were basically confined to the nest. During the second and third day following hatching, the chicks would follow the adults off the nest when the adults were foraging close to the nest and approached them when they returned to the nest with a food item.

Abandonment

At nest site 98-14, prior to the first egg hatching the adults turned both eggs on average 9.2 times per observation day (n = 9, SE = 0.7), following the hatching of the first egg the adults were not observed turning the remaining unhatched egg. This egg was abandoned two days later when the family departed the nest pond and later that same day a raven was observed on the nest. At the time the blind was set into place at nest 98-14 (10 days prior to the egg hatching), both eggs were floated and movement was observed and were therefore determined to be fertile. At nest 99-4, the adults were observed turning both eggs nine times during the observation session the day prior to the one egg hatching. On the following day with one chick in the nest, the adults turned the unhatched egg a total of eight times but were not observed turning the egg the following morning when the family departed the nest pond leaving the egg on the nest. This egg was later collected and was determined to be infertile. When the blind was put into place at nest 99-4 movement was detected in only one of the eggs. At nest site 99-5, the family group departed the nest with the first hatched chick and abandoned the younger chick on the nest (raven predation ensued). During the telemetry monitoring three additional chicks (all the smaller sibling) were considered to be abandoned prior to their death.

<u>Family Movements</u>

Between 1997 and 1998 no statistically significant difference was found between average daily movements of the family groups during the first week following departure of the nest pond. When compared with 1999, however, the family group's daily movements were significantly larger in 1999 than in 1997 (t-test, $P = 0.002$), and in 1998 (t-test, $P = 0.032$). Comparing the second week following hatching over the three years, family group's daily movements in 1999 were significantly larger than in 1997 (t-test, $P = 0.031$). The sample of observations during the third week in 1999 was too small for a statistical comparison. Of all family groups monitored in June, the only pair to successfully raise two young (97-23) had the second largest average daily movement listed in Table 2-3. The mean minimum daily movements of pairs with chicks in June were 358.0 (SE = 25.6) (Table 2-4).

In 1997 the average daily movements of pairs with two chicks was 258.0 m ($n = 8$, SE = 47.9) and in 1998, 332.0 m ($n = 4$, SE = 39.4), and in 1999 was 425.0 m ($n = 4$, SE = 116.1). Overall for the three years the average daily movement of pairs with two young were 317.0 m (SE=40.2). The average daily movement for nest pairs with 1 chick was 353.0 (n = 7, SE = 32.0). There was no statistically significant difference in daily movements between nest pairs with 1 or 2 chicks (t-test and one way ANOVA P=0.588)

Table 2-3: Daily movements of whooping cranes with two chicks, 1997-99.

1997

Nest Pair (1997)	N	Mean	SE
3-97 (A)	7	246.0	87
44-97 (B)	9	253.0	45.8
15-97 (D)	14	201	41
5-97 (E)	11	75.0	34.5
6-97 (F)	20	145.0	24.2
20-97 (K)	6	261.0	67.4
23-97 (M)	25	529.0	68.6
39-97 (N)	23	336.0	63.9

1998

Nest Pair (1998)	N	Mean	SE
8-98 (F)	9	287.0	55.8
40-98 (G)	10	252.0	79.7
18-98 (J)	13	429.0	64.2
15-98 (K)	3	360.0	85.4

1999

Nest Pair (1999)	N	Mean	SE
7-99	2	322.0	16.0
1-99	2	249.0	194.0
2-99	7	766.0	104.6
10-99	1	363.0	

Table 2-4: Minimum daily movements of whooping cranes with chicks during the month of June, 1997-1999.

1997

Nest Pair (1997)	N	Mean	SE
3-97*(A)	25	364.0	75.9
44-97*(B)	24	311.0	36.0
15-97*(D)	18	260.0	52.1
5-97*(E)	27	206.0	34.5
6-97*(F)	22	151.0	22.6
20-97*(K)	21	338.0	48.2
23-97*(M)	25	529.0	68.6
39-97*(N)	23	336.0	63.9

1998

Nest Pair (1998)	N	Mean	SE
4-98* (C)	9	264.0	75.3
8-98 (F)	9	287.0	55.8
40-98 (G)	10	252.0	79.7
18-98 (J)	13	429.0	64.2
15-98*(K)	11	311.0	39.6
14-98* (L)	10	258.0	40.1
20-98 (M)	8	361.0	74.8
23-98 (N)	8	409.0	102.3

1999

Nest Pair (1999)	N	Mean	SE
5-99* (A)	14	434.0	64.2
6-99* (B)	14	437.0	56.1
7-99 (D)	14	404.0	57.8
1-99 (F)	14	325.0	57.7
13-99* (J) (one obs 2 chicks)	12	450.0	74.6
2-99	9	750.0	80.6
10-99	3	360.0	29.8

*pairs with two chicks

Distance from Nests

Within two days of the second egg hatching (4 days from the first egg) the family groups moved from their nest ponds and each subsequent week the family groups moved farther from their nest sites. Over the 3 years a statistically significant difference was found in the average daily distance from the nesting areas between week 1 and week 2 following hatching (t-test, $P = 0.028$) and between week 1 and week 3 (t-test, $P = 0.003$). While there was not a statistically significant difference detected between week 2 and week 3, the mean for week 3 was 197 m further away than week 2.

Adult Behavior with young

Both adults were observed with the young on the majority (97%) of the observations, one adult was observed with the young on only 11 (3%) occasions. Most common types of behavior of the adults when young were present were standing, feeding, and walking respectively (Table 2-5). Adult 1 was identified as the adult brooding or closest to the young. Young were brooded on only 6% of observations and only rarely 1% was an adult observed flying. This does not include incubation observations.

Table 2-5: Adult whooping crane behavior with young

Behavior	Adult 1		Adult 2	
Behavior Adult (1)	N	%	N	%
Brood	20	6	0	0
Fed Chick	5	1	3	1
Preen	1	0.3	0	0
Probe (Feed)	110	32	103	31

Stand	177	51	158	47
Walk	35	10	68	20
Flew	0	0	5	1
Total	348	100	337	100

2.5 Discussion

This is the first study in WBNP to track whooping cranes chicks daily from hatching for their first few weeks. The average difference in weight between the two chicks from a brood was 47.6 g, this is a relatively large difference given that it is approx. one third the overall average weight of 149.1 g (n = 12, SE = 10.2) of the smaller siblings. Severe sibling aggression was displayed, particularly by the older (larger) sibling toward the younger smaller one. This study found that almost half the smaller siblings had outward signs of head trauma, and ground observations revealed serious aggression at the nest site. The family groups departed the nest site within two days following the second egg hatching resulting in the smaller sibling having to move before it is very strong. When combined, these factors resulted in many of the younger siblings being worn down. The smaller chick becomes weak and dies or gets abandoned and then preyed upon within two weeks of hatching. By June 15th most (80%) of the nesting pair's monitored had lost at least one of their chicks. Thus the proximate effects of sibling rivalry (being pecked repeatedly, fewer feedings, and the energetic requirements of remaining with a mobile family group) which ultimately led to abandonment appeared to be the major cause of mortality of the younger sibling.

Asynchronous Laying/Incubation/Hatching

Asynchronous hatching is characteristic of birds that have difficulty raising young (Miller 1973). Asynchronous hatching often results in the mortality of the smallest young, due in part to the inequitable distribution of food among the nest mates (not necessarily to food limitation) and as a direct result of the size disparities between nest mates (Stoleson and Beissinger 1997). Asynchronous hatching may also function to maximize the quality rather than the quantity of fledglings (Magrath 1989).

Lack (1954) proposed that asynchronous hatching is a behavioral adaptation that allows for secondary adjustment in brood size to match available resources. The bonus offspring is competitively inferior and if habitat conditions are poor, the older sibling can eliminate it's younger sibling with greater ease (Lack 1954). In an asynchronous hatching situation the first hatched has a head start and this represents the core brood whereas the second hatched is the marginal offspring whose survival is more variable and depends on ecological, social and developmental contingencies (Mock and Forbes 1995, Forbes et al. 1997). This over-production allows parents to capitalize when unpredictable environmental conditions are favorable and increase number of young produced, this has been referred to as the Resource Tracking Hypothesis (Temme and Charnov 1987); overproduction may allow parents to rear the full compliment (average) of young when various accidents happen to the older brood members, this has been referred to as the Replacement Offspring Hypothesis; and in some taxa the marginal offspring may provide help to the core members, or serve as a blanket or even a meal, this has been labeled as the Sibling Facilitation Hypothesis. I will examine these theories further.

Brood Rearing Strategies

The Resource Tracking Hypothesis suggests that parents attempt to take advantage of the occasionally very favorable habitat years, the problem is the unpredictable nature of future habitat conditions. As a result the adults produce the maximum number of eggs with the optimism that the conditions will be good enough to support all the young produced. In 1997, there was one nesting pair with two young that arrived on the wintering grounds. Water levels in the ponds sampled (Chapter 4) were highest in 1997 and it was the year that most young per nest were produced.

The Replacement Offspring Hypothesis has two components. The first one can be classified as progeny choice or the ability for the parents to choose the quality of young (Kozlowski and Stearns 1989). If the core offspring does not seem as robust as it should the parents have the option of choosing the offspring that they want to raise. The second component is insurance (Forbes and Mock 2000), where the extra offspring acts as potential replacement for core offspring if something should happen to it in the critical first few days following hatching (such as it gets injured, sick, or is killed by a predator). There was one occasion in this study where a predator took the larger core offspring (large sibling 8 days old) and then the pair had the second marginal offspring as an insurance backup (replacement) and in fact ended up fledging the younger marginal offspring.

Sibling Facilitation Hypothesis suggests the marginal brood member provides a service for the core member. It may involve providing direct nutrients when the core offspring kills and eats the marginal offspring when there is lack of resources for the young or it may be indirect by assisting in things like adding an extra thermal layer to keep the core offspring warm enough to metabolize food. This theory seems the least applicable to the whooping crane situation. At nests where two chicks were observed the two young were not observed huddled together for warmth, although when an adult was brooding them the exact position of the young could not be determined.

These three hypotheses are linked and by creating an extra egg the whooping crane parents simultaneously improve the thermal environment for core nestlings, obtain an insurance policy, and are prepared for the occasional good habitat year.

In this study, the older chicks were larger and possessed greater mobility than the younger smaller sibling. During the first day following hatching, when the younger sibling is confined to the nest, the older chick was able to walk off the nest and intercept the adults when they were bringing food items (see Chapter 3). At nest 99-16, this resulted in the older sibling receiving more feedings than the younger (smaller) chick (see chapter 3, Fig. 1). At nest site 99-5, the older sibling intercepted the adult by walking off the nest into *Scirpus validus* while the younger sibling on the nest did not receive any food items from the adults prior to being abandoned on the nest. At the two other nest sites where only one of the eggs hatched, the single chick displayed similar behavior and after the first day following hatching it often met the adults before they made their way to the nest and received the food item off the nest.

In birds where brood reduction occurs through sibling aggression like pelicans, eagles and cranes, the marginal nestling is usually bludgeoned to death at an early age (Cash and Evans 1986, Anderson 1989). In many facultative brood reducing species such as blue footed boobies (*Sula nebouxii*) and cattle egrets (*Bubulcus ibis*), the extra nestling is often maintained for days or even weeks. During this time the extra nestling is believed to have insurance value, if one of the older members perish it adds to the overall number of offspring produced (Mock and Parker 1986). The American white pelican (*Pelecanus erythrorhynchus*) generally lays two eggs but rarely raises two young with most of the nestlings perishing within the first week. Due primarily as a result of nest mate harassment and food deprivation. Consequently, the American white pelican is considered an obligate brood reducer (Cash and Evans 1986, Evans and McMahon 1987). In a study involving egg manipulation with the American white pelican parents without younger (marginal) chicks experienced the normal rate of hatching failure (20%) but had no back up, and those nests with three eggs did no better than parents with two, thus a second insurance egg yielded no additional benefit (Cash and Evans 1986). In a similar experiment with red-winged blackbirds (*Agelaius phoeniceus*), Forbes et al. (1997) found that the survival of younger offspring hinged on the fate of the older offspring, however adding or removing marginal offspring had no effect on the fate of core offspring. Comparable findings have been found in facultatively brood-reducing dark-eyed juncos (*Junco hyemalis*), european starlings (*Sturnus vulgaris*), and yellow-headed blackbirds (Smith 1988, Stouffer and Power 1990, Barber and Evans 1995). The presence or absence of young offspring has apparently little effect on the fate of the older offspring and represents a stock of relatively cheap disposable offspring (Forbes and Mock 2000).

The costs of evicting surplus young nestlings may also extract high energetic costs, although it might also serve as a screening process for low-quality core offspring (Simmons 1988). In obligate brood reducers there is usually at least a two day age difference, so an older sibling that cannot defeat its newly hatched sibling may not be worth raising (Forbes 1991). Parents of siblicidal species will often not protect the younger sibling or try and sneak food items to the smaller chick; parents generally do nothing to interfere with sibling aggression (Mock et al. 1990). Parents do not interfere because it would be delaying the inevitable (Drummond 1993).

In the only other ground observations of whooping crane chicks in WBNP, severe aggression between the chicks was observed (Muir 1976). Based on Muir's (1976) observations at a nest site, the first egg hatched on June 2 and the second egg hatched on June 4. Two hours following the second egg hatching the adults were off the nest on the opposite end of the pond leaving the younger chick by itself on the nest. The adults slowly made their way back to the nest and one adult brooded the younger chick while the other adult remained with the older chick. On June 5, Muir (1976) observed that whenever the two chicks were close to one another they would vigorously peck one another. The family was last observed at the nest on June 7 and by June 8 did not return.

In this study, five nesting pairs were observed with only one egg in their nest, only one of these pairs fledged a chick and this pair did not arrive on the wintering grounds with a chick. While the chance of fledging a chick should be higher in a one egg clutch there is no second younger chick to serve as insurance if something should happen to the older chick. Adult interference with the chicks during aggressive exchanges was not observed at the nest sites. Based on what was observed in this study it appears whooping cranes are somewhere on the continuum between obligate and facilitative siblicidal brood reducers and the second egg is not a "biological surplus" (Edwards et. al. 1994) but plays an insurance role. In this study, the younger sibling fledged at least 13% of the time (this is a minimum number because in 1997 without transmitters attached it was not possible to determine which of the young survived).

In a study of 142 greater sandhill chicks at Malheur National Wildlife Refuge in Oregon, five chicks (4%) were lost to intra-specific aggression (Ivey and Scheuering 1997.

Once greater sandhill young leave the nest they are kept 5-15 m apart by the parents during the day but the female still broods both chicks together at night (Littlefield and Ryder 1968). Even though the chicks are intentionally separated, aggressive interactions still take place (Drewian 1973).

Quale (1976) found that in sandhill chicks level of aggressiveness was related to hunger and speculated that both chicks would starve if not for this behavioral tendency of one chick attacking its sibling , in all cases observed by Quale the larger chick was the aggressor. Natural selection has not eliminated the second egg in species like cranes since sibling rivalry is often an efficient method of reducing brood size and the insurance value of an extra egg is greater than its energetic cost. Greater sandhill chicks are so aggressive that the parents often raise the young separated until the age when the aggression becomes less severe (Littlefield and Ryder 1968).

Watanobe (1996) conducted experiments to compare the behaviors of whooping crane and sandhill chicks. Watanabe (1996) found few differences between the species in development and frequency of behaviors but did find significant differences in the timing of the inter-chick aggression and response to predators. Whooping crane chicks displayed their peak aggression at 23 days while the sandhill chicks were most aggressive at three days this may be due to whooping cranes slower physical development (Watanabe 1996). Whooping crane chick aggression peaked between 8 and 30 days following hatching. When the chicks are older and less dependent on the adults for food levels of aggression became less which may indicate that aggression and food are connected (Wantanabe 1996). During the first 3-4 weeks the chicks tended to be within 1 m of their parents, after that 2-4 meters. Whooping crane chicks seem to be quite dependent on their parents while greater sandhill chicks were more independent (Wantanabe 1996). Watanabe, (1996) found that after 30-40 days both species exhibited decreased levels of aggression when the chicks can forage to some degree on their own (Horwich 1989), indicating that aggression may be food related (Watanabe 1996). As the chicks grow rapidly and require more food, the adults may be limited in the quantity they can provide and as a result, the aggression may peak at this time (Watanabe 1996). Watanabe (1996) speculated that the aggressive behaviour of both species of cranes typically results in the survival of only one chick in the wild (Watanabe 1996).

In a study conducted with Florida (*G. c. pratensis*) and greater sandhill chicks the level of aggression among chicks increased greatly when the sandhill chicks were hungry

(Quale 1976).

In this study, all but one of the dead chicks lost weight from the time of capture, although typically captive reared cranes lose 10-15% of their body weight as they absorb their yolk sacs during the first week (Ellis et al. 1996). Only one chick carcass (99-1b) was considered to be emaciated and it had evidence of severe head trauma. In 1998, the four chicks that were given a physical all appeared to be in relatively normal condition including the smaller siblings (Cooper pers. comm. 1998). All but one of the pairs with twins lost at least one chick within 23 days following hatching and most pairs (88%) lost at least one chick within two weeks of hatching. Nesting pair 97-23 successfully raised both young.

During this study aggression of the chicks was observed immediately following hatching. One reason for difference in timing of aggression of wild crane chicks vs captive crane chicks may be the result of captive cranes having unlimited access to food whereas in the wild the crane chicks do not and as a result the wild chicks become aggressive earlier than captive reared ones.

Predators and Scavengers

Whooping crane egg and chick loss in WBNP has been recorded for many years. Predation has played a direct role in chick mortality. In 1973, a nest was abandoned and the egg disappeared three days later. In 1975, a nest with two eggs in each of these years respectively was destroyed approximately two weeks prior to egg collection. In 1976, a nest with one egg was abandoned and shell fragments were on the nest. This particular pair may have re-nested and laid two eggs but these eggs did not hatch either (Kuyt

1981). In 1977, a rare clutch of three eggs was discovered to be destroyed, by what appeared to be large birds (Kuyt 1981) and in 1978 a black bear's (*Ursus americanus*) tracks indicated that it had raided a nest of eggs prior to hatching (Kuyt 1981). In 1979, a wolf (*Canis lupus*) killed a juvenile whooping crane in August (Kuyt 1981). In 1980 a nest was found empty during egg collection with a trail of a large mammal (likely a bear) leading to the nest (Kuyt 1981). An additional nest in 1980 was found to be abandoned and only fragments of the egg shell remained again evidence pointed to a mammal having eaten the egg (Kuyt 1981). Between 1982 and 1983, Kuyt (1992) suspected that wolves took 6 of 12 radio tagged young whooping cranes in August and September. During the 1996 egg collection, one egg collected at a nest was empty and had a four by five cm hole punctured in it, the result of a large avian predator/scavenger (Johns pers. comm. 1996).

Between 1975-1988, 215 whooping crane eggs from WBNP were placed in greater sandhill crane nests at Grays Lake, Idaho in an attempt to reintroduce wild whooping cranes into the Rocky Mts. Due to behavioral differences between the two species there were no successful mating of whooping cranes and no young produced. Most of the whooping crane chicks that went missing during the Grays Lake cross-fostering experiment occurred within the first 30 days following hatching. Coyote (*Canis latrans*) and red fox predation were the primary cause of egg loss. Primary causes of fledged whooping cranes at Grays Lake were power line collisions (40%), collisions with fences (22%), disease (18%), and avian predation (7%) (Kuyt 1996).

In a mortality study on greater sandhill crane chicks at Malheur National Wildlife Refuge, 142 chicks were radio-equipped and of these only 23 chicks fledged (16%).

Predators were responsible for most chick deaths (64), and of these 26 were lost to mink (*Mustela vison*), 10 to great horned owls (*Bubo virginianus*), and nine to golden eagles (*Aquila chrysaetos*) (Ivey and Scheuering 1997). A previous study conducted at Malheur in 1983 and 1984 indicated that predators were severely limiting crane chick survival, and coyotes were taking the majority of the crane chicks (Littlfied and Lindstedt 1992). Consequently a predator control program was initiated to reduce coyotes and while it was successful, it appears that mink replaced coyotes as the main predator on young chicks at Malheur (Ivey and Scheuering 1997).

A similar study of greater sandhill crane chick survival was conducted in Modoc National Wildlife Refuge in California DesRoberts (1997) found chick survival rates to fledging were 0.3 in 1990 and 0.5 in 1992. Coyotes and mink took three and four chicks respectively and were the major causes of known mortality. Coyotes, racoons (*Procyon lotor*), red foxes, ravens, and golden eagles are reported as common predators of greater sandhill chicks (Drewian 1973, Drieslein and Bennet 1979, Paullin 1988).

In a study of chick mortality of Florida sand hill cranes (*Grus canadensis pratensis*), Nesbitt (1996) found that 55% of chick mortality occurred before the chicks were 10 days old. Predation was the main source of mortality, with 83% of the known losses due to suspected predators such as coyotes (C*anis latrans*), bobcats (L*ynx rufus*), and bald eagles (*Haliaeetus leucocephalus*) (Nesbitt 1996).

In a study comparing behavioral differences between captive whooping crane chicks and greater sandhill chicks' responses to a "simulated" predator, Watanabe (1996) found that the distance from a whooping crane chick to its nearest parent at the sight of a predator increased as age increased. During the first three-four weeks the chick remained within 1 m of its parents, however after this time the chick remained 2.5 to 4 m away when a predator was near (Watanabe 1996). Only on rare occasions did a whooping crane chick run from a predator. Their typical response was to remain motionless. Whooping crane chicks tended to be dependent on their parents and remained close when a predator was near whereas greater sandhill chicks were comparatively independent and often ran away from their parents (Watanabe 1996). At Grays Lake, during the cross-fostering experiment, whooping crane chicks raised by greater sandhill cranes moved to open water when a predator approached (Drewien and Kuyt 1979).

In this study, three small chicks were suspected to have been killed by predators, two by foxes (both older siblings) and one by a raven (younger sibling), and one observed case of predation where a raven took the live smaller sibling off an abandoned nest. In this study, when the family groups were approached on foot (transmitter attachments), the chicks behavior depended on how long it took to get to their location. If it took 2-3 minutes the chicks would remain still in the vegetation close to where the adult(s) were observed initially, if it took longer to get to the pond, the chicks would follow the adults for 10-50 m before remaining motionless in the vegetation. The chicks that were in a pond when approached remained in the water, and chicks that were along the shoreline or on the ridges surrounding the ponds remained still in vegetation along the shoreline or ridge.

Precipitation

A total of 20 chicks that were closely monitored went missing between 1997-

1999. Of these 20, precipitation was recorded in the preceeding 24 hr period of 15 of these missing chicks. Young birds are most vulnerable to weather extremes before they can adequately thermoregulate, and rely mostly on their parents to keep them warm and dry (Newton 1998). Spring snowstorms may result in the small chicks being extremely vulnerable to exposure (Ojanen 1979). Summer rainstorms have killed many young birds especially when they occur soon after hatching, as indicated by the 90% chick mortality recorded at a herring gull (*Larus argentatus*) colony in Newfoundland (Threlfall et al. 1974). The young of nidifugous birds seem especially susceptible to rain following hatching (Newton 1998).

Water levels in the whooping cranes nesting area seemed to be strongly dependent on precipitation. The occurrence of droughts in the region appeared to have a strong effect on the water levels in the ponds and ground water discharge was insufficient to maintain levels without precipitation input (McNaughton 1991 unpublished). In 1997 and 1998 the annual (May 1 to April 30) precipitation prior to nesting was similar, 401.3 mm and 407.5 mm respectively and was higher than the 49 year average of 352.0 mm (Johns 1999 unpublished). However, the annual precipitation prior to nesting in 1999 was only 259.3 mm which was the lowest recorded in the previous 19 years. In 1999, family groups moved the farthest from the nest sites over the three years monitored and the family groups in 1999 also had the largest daily movements during the month of June. In addition, 1999 had the fewest number of chicks survive to fledging. In WBNP, annual production of juveniles was significantly correlated with mean water depth at nest sites (Kuyt 1992). When water is low in the wetlands there may be greater energetic demands placed upon the young chicks as the family group moves further distances. While traveling between ponds the chicks may also be more vulnerable to terrestrial predators such as foxes, coyotes, mink and wolves. Drier conditions prior to the nesting season of 1999 may have resulted in less re-charge of the ponds and reduced fish distribution. Therefore the family groups had to move further distances in search of food, resulting in the smaller, weaker chicks falling behind and eventually being abandoned. Thus precipitation may have played a role in chick mortality directly through adding to the stress of maintaining thermoregulation or indirectly through lowered resource abundance.

Abandonment

Kuyt (1995) found that over 90% of nests contained two eggs. During the three years of monitoring the nesting whooping cranes in WBNP there were 148 nests observed. Over those three years there should have been approximately 133 (148 x 0.90) nests with a clutch of two eggs. Kuyt (1996), also found that hatching success was between 70-80%, therefore there should have been 100 (133 x 0.75) nesting pairs over the last three years with two young at hatching. However, only 38 pairs with two young were observed prior to mid June. Nesting pairs lost or abandoned their second young in 62% of the nests before mid June.

Based on the ground observations from this study, there were two instances where the family group departed the nest when the first chick was mobile (two-three days old) and the adults abandoned the second egg on the nest. At least one of these abandoned eggs was thought to be fertile several days prior to abandonment (Johns pers. comm. 1998). Based on the telemetry monitoring over the three years, there were three instances when the adults appeared to abandoned a chick, all three occasions it was the smaller sibling. Although with one of these apparent abandonments, chick 99-10b, it was the only chick that pair 99-10 were tending when it was left, as the older sibling went missing two days earlier. There were five observed likely abandonments in total out of 148 nesting attempts (3%). Abandonment of eggs on nests and young chicks is difficult to ascertain as the young are difficult to observe from the air.

Harpy eagles (*Harpia harpyja*) lay two eggs and when the first one hatches the second egg is buried. Hooded Grebes (*Podiceps gallardoi*) lay two eggs, when the first egg hatches, the family abandons the second unhatched egg (Forbes 2005) .

Note: Although it should be noted that in most years one or two nesting pairs that do not hatch their eggs remain incubating eggs at the end of June and even as late as the second week in July, four to five weeks past expected hatch dates.

Evaluation of Researcher Handling Impacts

The capture of whooping crane chicks and attachment of transmitters resulted in temporary disturbance and stress to the chicks and the adults. When the helicopter landed, the adults generally walked off anywhere from 20-50 m, paced back and forth, displayed, called and then after two-five minutes would walk out of sight or fly off. Handling times varied from 7 minutes to 23 minutes with an average of 16.1 minutes (n = 14, SE = 1.6). Total time from when the helicopter landed until it departed at each site was an average of 28.1 minutes (n = 14, SE = 1.8).

Whooping cranes grow from hatching size to near adult size between 80-90 days (Edwards et al. 1994) and as a result a permanent marker cannot be attached to a hatchling. In a study (1996-1999) of Florida sandhill crane chicks, different types of transmitters and attachment techniques were compared (Spalding et al. 2000). In 1996, transmitters (≤ 5 g) were glued and then sutured on to the backs of five and 10-19 day old chicks. Only one of these five survived to fledging. Between 1997-1999 transmitters (≤ 2 g) were glued onto 22 chicks ranging in age from 1-11 days. Eight fell off or were pulled off before recapture and two transmitters failed. Subcutaneous transmitters (≤ 4 g) were placed into 19 chicks between 7and 32 days of age. Two transmitters fell off before the chicks reached 55 days of age, in both cases the chicks were < 10 days old when the transmitters were attached. These types of subcutaneous transmitters were found to be unsuitable for chicks less than 10 days of age. Spalding et al. (2000) concluded that glue-on transmitters were the preferred method on chicks < 10 days old and the subcutaneous method for chicks > 10 days. Nesbitt and Schwikert (1999) found no difference in survival between Florida sandhill chicks that had transmitters with those without transmitters.

Back-mounted transmitters (1.8-2.0 g) were sutured on to the backs of day old wild mallard (*Anas platyrhynchos*) duckling’s (Machin 1998) . Death of ducklings with transmitters was significantly greater than ducklings without transmitters in the control group. Ducklings with transmitters preened the surgical area often and at the end of the study weighed less than the control group. The ducklings with transmitters also had increased surface temperature suggesting heat loss may be associated with transmitters. Transmitters may also disrupt plumage thereby increasing thermoregulatory loss. The major cause of death in the ducklings with transmitters was hypothermia. Overall, it was concluded that transmitters can have negative effects on wild ducklings and can make them more susceptible to mortality from starvation, exposure, predation and parasites (Machin 1998). In this study, no chicks were injured during capture and handling although the stress involved may have been additive to other factors such as infection, exposure and sibling aggression resulting in a chick (particularly the smaller one) being slowed down and ultimately abandoned. Timing of losses of chicks in this study were comparable to losses in non study chicks. In 1998, when the last study chicks had gone missing no other pairs of chicks remained from the six additional pairs of chicks observed in the remainder of the population. In 1999, when the last study set of chicks went missing there was one remaining set of chicks out of four additional pairs that remained in the rest of the population. One week later, this late nesting pair also lost one of their chicks.

In 1998, a remote surveillance camera was set up 60 m from a nest. Following two monitoring flights over the nest site without observing the nesting pair, it was determined that the nest was abandoned and as a result the eggs were collected. The fertile eggs were shipped to the Calgary Zoo. One chick survived hatching (and remains in captivity) while the other chick died during hatching. It is thought by the researcher that the length of time to set up the camera (a total of 50 minutes from landing until departing) was responsible for causing the abandonment.

Conclusions

The goal of a breeding pair of whooping cranes is to raise two healthy young per year even though they rarely achieve this goal. So why do whooping cranes continue to lay and incubate two eggs but then usually end up rearing a reduced brood? One explanation is that when whooping cranes arrive on their nesting grounds many ponds are still ice covered and predicting what the following summer's resources is difficult so they lay two eggs in case the summer turns out to be above average. In addition, if there are any problems with the first egg hatching or if the first chick is not functioning normal the second egg is a backup. Once the first egg hatches and appears to be functioning normal the adult whooping cranes will sometimes lose interest in the second egg neglecting to turn the egg, and even abandon the egg on the nest. If both eggs do hatch often the older sibling out competes the younger one for food resources (as the adults feed the first chick that approaches them which was often the older larger one, see chapter 3). The older sibling also exhibits aggression through pecking the younger sibling repeatedly. The family group departs the nest pond within two days of the second egg hatching, when these factors are combined the second young ends up being worn down and eventually lags behind and gets preyed upon or abandoned by the adults.

However out of 22 sets of twins monitored, 16 young were fledged, of these at least two (13%) were the younger siblings. One older core sibling was preyed upon and the adults had the second offspring as insurance and fledged the marginal offspring. In 1997 the habitat, (water levels highest of the 3 years) two whooping crane pairs raised both chicks to the fledging stage and one pair made it to the wintering grounds with both young. The Resource Tracking and Replacement Offspring Hypotheses seems to fit the closest to what was observed with nesting whooping cranes.

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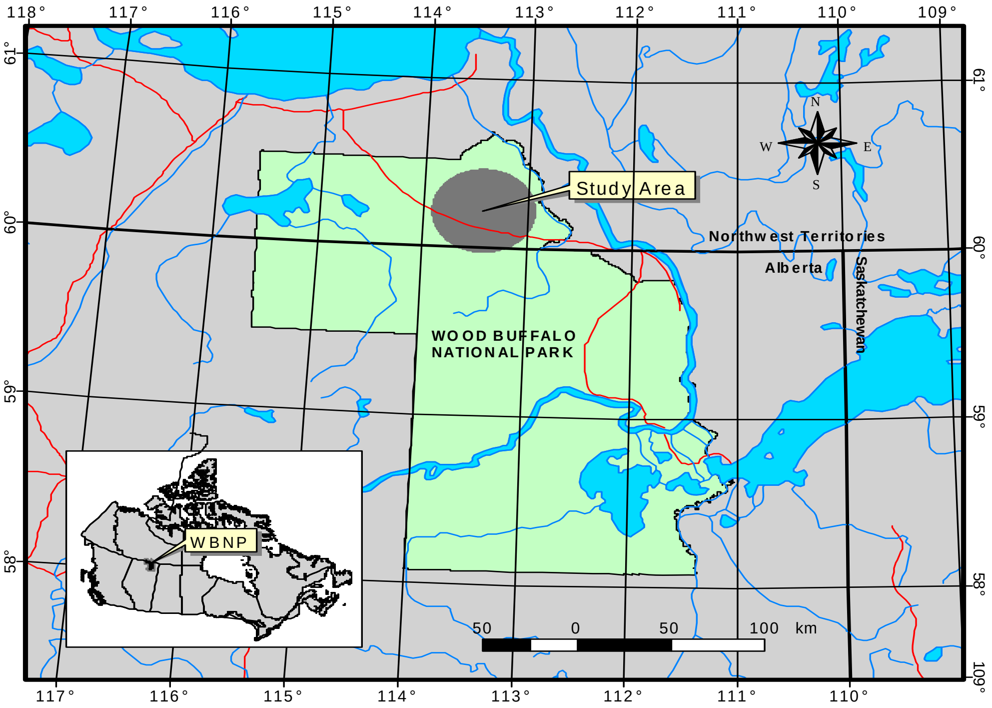
Figure 2-1: Study Area.



Chapter 3

DIET OF WHOOPING CRANE CHICKS

Introduction

Wetland marshes in and around Wood Buffalo National Park (WBNP) represent the only continually inhabited breeding grounds of the endangered whooping crane (*Grus americana*) in the world. Whooping crane nesting sites were first observed in WBNP in 1954 (Fuller 1955 Unpublished) when five pairs were located. The current (2007) population numbers close to 235 individuals.

The abundance of aquatic insects the previous year often translates into the number of fledglings produced per female in many species of ducks (Newton 1998). Food supplies can have an impact on breeding bird densities through the survival of adults, production of young, or influence on immigration/emigration (Newton 1998).

There is little information that exists with regard to potential limiting factors of wild whooping crane chicks. The purpose of this study was to determine the diet of young whooping crane chicks and gain information on why few wild whooping crane twins survive. This information will aid resource managers in understanding and evaluating nesting habitat in relation to potential range expansion and future re-introduction efforts.

Study Area

For description of study area refer to study area in Chapter 2.

Objectives:

Identify diet items of selected whooping crane chicks in WBNP.

Determine fourth order habitat selection (Johnson 1980) of young whooping cranes.

Determine whether there were feeding disparities between whooping crane siblings.

Methods

In May 1998, an enclosed plywood blind was set up 70 m from a whooping crane nest (98-14). The blind had viewing ports on three sides and its dimensions were 120 cm by 120 cm in width and 195 cm in height. The blind was slung into place using a helicopter (Aerospatiale A-Star). At the same time, the eggs were floated to determine if they were fertile and to get an approximate hatching date. Time spent observing from the blind varied from two to eight hours per day. In total, 22 hours were spent in the blind observing nesting behavior following the hatching of one egg (98-14). Information recorded included: feeding attempts of each chick; items consumed by each chick; and which adult was feeding each chick.

In May 1999, three blinds were placed 70 m from three nests (99-4, 99-5, 99-16). The blinds utilized were identical to the one used in 1998 and were put into place in the same manner. Observation from the blinds lasted from two to six hours and varied from two to five days until the family group departed the nest pond. At nest site (99-4) a total of 14 hours were spent observing the chicks feeding pattern prior to the family group departing the nest pond. At nest site (99-5) a total of 15 hours were spent observing the feeding patterns of this chick. Information recorded was identical to 1998.

Sex of the individual adults was determined by banding status at nests 4 and 5, and by size at nests 14 and 16. Food items were examined from the stomachs of five dead chicks that were retrieved as part of the chick mortality study using radio-telemetry.

Results

1998

The chick began pipping out of the egg (98-14) on the afternoon of June second, and the chick was first observed at 08:30 hours on June third. The first feeding attempt occurred at 08:56 and the first observed item the chick consumed was a dragonfly nymph. The chick was observed to be successfully fed 19 times over a 7 hour period. Successful feeding occurred an average of every 18.58 minutes (n = 19, SE = 6.4). On the second day this chick was observed to be successfully fed 11 times and the adults fed the chick on average every 32.7 minutes (n = 11, SE = 14.3). The majority of the feedings (61%) occurred between 09:00 and 11:00 hours over the two days. The female (male and female both were unbanded and distinguished by size) did the majority of the feeding (71%) (22 out of 31). The majority (81%) of the adults probing attempts occurred in wet bulrush in the nest pond. Only two (6%) of the successful feedings occurred when there was only one adult present.

The adults did little feeding in the nest pond itself and flew off to other areas to forage. The average time one adult was absent from the nest pond was 116 minutes (n = 3, SE = 16.9). It should be noted that the adults paid little attention to the remaining egg following the first egg hatching. During the nine observation days prior to the chick hatching the adults turned both eggs on average 9.22 times per day (n = 9, SE = 0.7).

1999

The chick (99-4) hatched in the evening of May 26. The first observed feeding attempt occurred at 10:06 on May 27 and the first observed item consumed was a dragon fly nymph. The chick was observed to consume nine items over a five hour period, being fed on average every 14.88 minutes (n = 8, SE = 7.8). The majority of the feedings (78%) occurred between 11:30 and 14:30 hours. The male (banded) did the majority (67%) of the feedings. During all the successful feedings both the male and female were present. On four occasions the adult (female) dipped her bill in water and dripped water over the chick. The adults foraged in the nest pond in wet bulrush (56%) and open water (44%). The adults did not forage a great deal in the nest pond for themselves and flew off to other areas, the female did so four times and the male two times. The average time an adult was gone was 76.0 minutes (n = 5, SE = 23.4). The female was observed to do most of the brooding (70%) of the chick. The adults turned the eggs nine times on May 26, and turned the remaining egg eight times on May 27. On May 28, they were not observed turning the egg and left the unhatched egg on nest. This egg was collected at 18:30 hours. Chick 99-4 was fed almost exclusively (89%) dragonfly nymphs. Chick 99-4 swam in open water on the first day following hatching and gained greater mobility as the day went on. In the afternoon the chick was walking three to five meters to meet the adult with food items. On May 28, the male along with the chick departed the nest at 09:00 to an island to the south 10 m away and did not return. A few hours later the male and chick moved to a third island 30 m away and later in the day moved to the south shore of the pond an additional 43 m away resulting in the family group being 177 m away from the blind. Adults appeared to be feeding the chick on a small island in the nest pond but they were too far away for positive verification.

At nest 99-5 both eggs did hatch, the older chick was estimated to be three days old and the younger one less than 24 hours old when the observations sessions began. However the younger chick did not receive any food items from the adults prior to it being abandoned on the nest and a raven (*Corvus corax*) taking it. The older chick was observed to be successfully fed six times over a nine hour period, and was fed five times by the female and once by the male (banded). Prior to the younger chick being taken whenever an adult approached the nest the older chick would walk off the nest and intercept the adult, often resulting in obtaining a food item. It should be noted that since this chick was older it spent a significant part of the observation day in the bulrush and out of view of the observers and as a result several feedings may have been missed. Most (66%) of the foraging for prey items for the chick was in bulrush and open water (34%). The adults did little feeding in the nest pond for themselves and flew off several times, the average time an adult was gone was 53.5 minutes (n = 4, SE = 16.6). The female was observed doing all of the brooding of the chick(s) at this nest site. This pair was observed to unison call six times with five of these occurring between 05:30 and 07:30 hours. The only observed items this chick consumed were dragon fly nymphs. The female did take what appeared to be a leech to the chick but the chick was not observed consuming it. The majority of the feeding (67%) occurred when both adults were present and the female did most of the feedings. The family group departed the nest pond on the morning of the fourth day following the hatching of their first egg.

Of the four nests, two hatched both eggs, and two hatched only one egg. Of the nests with two chicks, one lost the younger chick to a raven just 2.75 hours after observations began, so nest 16 is the only nest with feeding data for a two-chick nest. A summary of the events and observation sessions are in Table 3-1.

Table 3-1. Chronology of events and hours of observation for each nest.

	1998	1999		
Nest	14	4	5	16
*Hatch Day	1 chick	1 chick	1 chick	1 chick
Hatch Day+1	1 chick	Depart Nest	1 chick	1 chick
Hatch Day+2	Depart Nest		2 chicks, young chick	2 chicks
Hatch Day+3			Depart Nest Pond	2 chicks
Hatch Day+4				Depart Nest
Observation hrs	22 (3 days)	14 (2 days)	15 (2 days)	42 (5 days)

*Hatch day is the first sunrise to sunset period following hatching. Chicks at the start of a hatch day could be anywhere from 0 to 12 hours old, since only one chick was observed hatching; the others hatched while being brooded or between observation sessions.

Fourth order habitat selection

At all nests, dragonfly nymphs were the predominant diet item (Table 3-2). The ratio of dragonfly nymphs to others was consistent among nests (Table 3-2) and between the old and young chick in nest 16. Overall dragonfly nymphs made up 89% of known food items (n = 156). Dragonfly nymphs in the nesting ponds are from two genera (*Aeshna* and *Libellula*). Of the unknown food items 75% were of dragonfly nymph size or smaller.

Table 3-2. Diet items consumed by whooping crane chicks.

Year	1998	1999				
Nest	14	4	5	16		
				Old Chick	Young Chick	Old/Young
Dragonfly Nymphs	19	8	4	90	7	10
Adult Dragonfly	1			2	1	4
Egg Membrane				7		
Snail		1		1		
Fly				1		
Unknown	14	5	2	81	17	34
Total	34	14	6	182	25	48
%Dragonfly Nymphs (excluding Unknowns)	95	89	100	89	88	71

Food Deliveries by Adults

In three of the four nests, the female made the majority of the food deliveries (Table 3-3). Overall, females made 66% of all food. At nest 16, where it was possible to compare feeding deliveries between the siblings, the male made 90% of his deliveries to the older chick (n = 76), while the female made 86% of her food deliveries to the older chick (n = 141). At nest 16, the older chick fed itself on parts of the egg membrane six times and caught and ate one fly.

Table 3-3. Number of food deliveries by each adult.

	1998	1999		
Nest	14	4	5	16
Female	22	3	5	164
Male	9	6	1	84
Total	31	9	6	248
% Female Feedings	71	33	83	66

Feeding Rate

The younger chick at nest 16 received fewer food items than its sibling, when compared at similar ages (Fig. 3-1). The younger chick at nest five did not receive any food items prior to being abandoned by the family group. The abandoned chick was subsequently preyed upon by a raven.

In all nests, chicks were fed exclusively in the nest on the first day after hatching. On the second day, most feedings were still in the nest, but the chicks were starting to move out of the nest. On the third and later days, most feedings were away from the nests, as the chicks were following the parents during foraging.

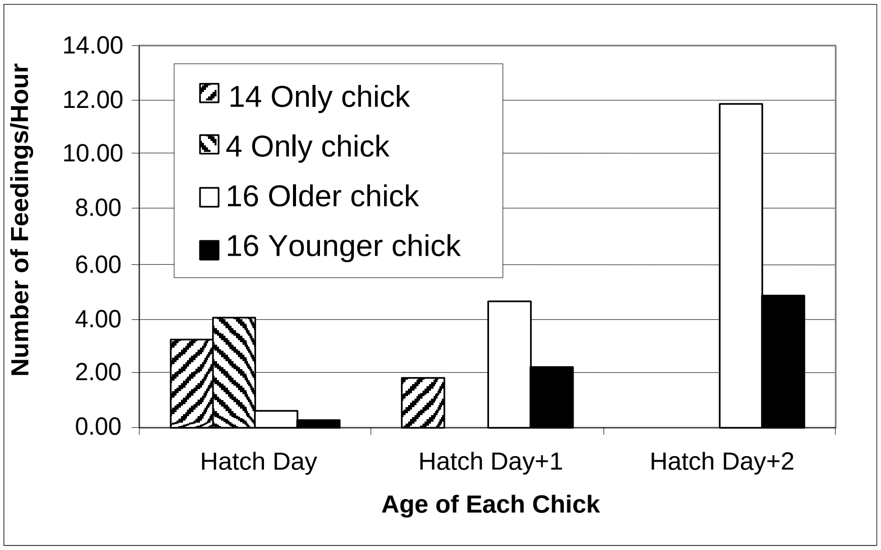


Figure 3-1: Number of feedings/hour.

Chick Necropsies

In 1998, two chick carcasses were located by radio-telemetry during the chick mortality study (Chp. 2). One carcass was too decomposed to identify food items in its digestive tract. However, necropsy results revealed the other chick's digestive system was filled with parts of dragonfly nymphs. No other food items were present.

In 1999, three chick carcasses were located by radio-telemetry during the chick mortality study (Chp. 2) . Necropsies revealed that all three had various amounts of dragonfly nymphs in their digestive systems. No other food items were present.

Discussion

At all the nest sites and in each of the four chick carcasses examined in this study, dragonfly nymphs were the predominant food item consumed by young whooping cranes. The only other nest observation conducted in WBNP occurred in 1974 and during this observation session it was also observed that insect larvae were fed to the young chicks (Muir 1976).

This is the first study to report on the division of feeding duties by parent for wild whooping cranes. Both parents are active in feeding the chicks, with the females providing the larger share. The males often adopted an alert posture while the females foraged and fed the young. Feeding rates for the younger chick at nest 16 were lower than for the older sibling. The parents did not appear to focus on feeding any particular chick, but fed whichever was closest. This was often the older chick due to its increased mobility. Chicks older than one day often intercepted foraging adults on their way back to the nest, thus receiving the food item and effectively preventing the younger chick on the nest from feeding. The disparity in feeding rate for the older (and only) chicks on their hatch day may be due to a difference in ages. The older egg (chick) at nest 16 hatched out after observations began, whereas at nests 14 and 4 the eggs hatched sometime the previous evening. Nests 14 and 4 chicks could have been as much as 14 hours older than the older chick at nest 16.

Conclusions

The diet of young whooping crane chicks consists primarily of dragonfly nymphs.

The fourth order selection for whooping crane young is dragonfly nymphs. At nest sites where two eggs hatched the first hatched older egg (chick) received more feedings than the second hatched younger egg (chick).

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Chapter 4

HABITAT USE PATTERNS, FORAGING ECOLOGY AND DIET OF ADULT WHOOPING CRANES

Introduction

Wetlands in and around Wood Buffalo National Park (WBNP) represent the only continually inhabited breeding grounds of the endangered whooping crane (*Grus americana*) in the world. Whooping crane nesting sites were first observed in WBNP in 1954 (Fuller 1955 Unpublished) when five pairs were located. The current (2007) population numbers close to 235 individuals and 65 breeding pairs.

Prior to European settlement of the Great Plains the historic breeding range of the whooping crane extended from central and northern Alberta across southern NWT, southern Saskatchewan, southern Manitoba, North Dakota, Minnesota, northern Iowa and southeast to central Illinois (Allen 1952, Johnsgard 1983). Non migratory populations existed in Louisiana (Lewis 1995) and possibly Florida (Nesbitt 1982). Estimates of the number of whooping cranes in the early 1800s varied from 500 (United States Fish and Wildlife Service 1994) to 1800 individuals (Allen 1952). During the late 19th century whooping crane numbers declined rapidly as significant amounts of grasslands and associated wetlands were converted to agricultural production (Allen 1952; McNulty 1966). At the same time whooping cranes were hunted for their meat and feathers, and eggs were collected for specimens and food (Allen 1952). In 1970, the whooping crane was listed as an endangered species in the United States (Cannon 1996). In Canada the whooping crane was designated as endangered in 1978 (Canadian Wildlife Service and

U.S. Fish and Wildlife Service 2005). In 1978 several wetlands in the United States were designated as critical habitat, including: the Aransas Wildlife Refuge and surrounding area; Cheyenne State Waterfowl Management Area; and Quivira National Wildlife Refuge, Kansas; the Platte River area between Lexington and Denman, Nebraska; and Salt Plains National Wildlife Refuge, Oklahoma. In Canada, critical habitat has been identified as the following: the breeding grounds in and around WBNP; Last Mountain Lake and Stalwart National Wildlife Areas; the Last Mountain Lake Migratory Bird Sanctuary; and the South Saskatchewan River and its sandbars between Outlook and Saskatoon; as well as the area between Meadow Lake, Swift Current, Estevan and Quill Lakes is considered as a staging area for whooping cranes (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005).

Parks Canada, the Canadian Wildlife Service (CWS), and the United States Fish and Wildlife Service have conducted annual surveys over the nesting grounds recording the number of cranes, nest locations, chick production and fledgling success since 1967. Although these aerial surveys provide excellent trend information, little information existed on habitat use and the diet of nesting whooping cranes.

Prior to potential reintroduction sites being evaluated adequately, the nesting habitat and diet requirements of the whooping cranes in WBNP needed to be better understood. This chapter presents the results of a three-year study (1997-1999*)* initiated by Parks Canada and the CWS in WBNP to describe at different spatial scales the whooping crane’s use of habitat and determine the main components in the whooping crane’s diet in WBNP.

Objectives

a) to determine habitat selection (third order resource selection Johnson 1980) and the habitat use patterns of nesting whooping cranes;

b) to determine the prey selection (fourth order Johnson 1980) of whooping cranes on their nesting grounds;

c) to describe the foraging strategy of family groups of whooping cranes through the summer months and compare these findings with the whooping cranes winter foraging strategy.

Research Questions

Do Whooping cranes select for ponds with certain abiotic and biotic characteristics?
What are the characteristics of habitats where whooping cranes forage at third and fourth order selection?
What are the primary items that comprise the whooping cranes summer diet?Can captive naïve whooping cranes capture wild prey and would they select for certain taxa, size or shape of prey?

Study Area

The study area is located in the northwest quadrant (59^0 45' - $60^0$30'N, and 112^0 45' - 113^0 55' W) of WBNP. A complete description of the study area can be found in Chapter 2.

Methods

Several factors were considered to determine what type of survey techniques could be used in the whooping crane’s nesting grounds. These included: disturbances to the low number of whooping cranes (less than 300 in the wild); the remoteness of the area (ground access limited to helicopter); sensitivity of the habitat (wetlands are fragile); and high degree of protection (the area is classified as a Zone 1 which receives the highest protection afforded in Canadian National Parks).

Habitat Use and Foraging Ecology

During the aerial surveys, information was recorded on the whooping cranes location and behavior when they were first observed. Use of initial observation was preferred for estimating common foraging locations of birds (Hejl et al. 1990). A single record was taken of each individual observed during each survey so as to maintain independence between data points (Morrison et al. 1992) and included recording the location of a whooping crane at the time of the initial observation and plotting its position onto a clear plastic mylar which was attached to an air photo (false-colour infra-red, scale 1:15,840).

Habitat use was measured at the third and fourth order selection as defined by Johnson (1980). At the third order scale habitat in which the cranes were observed, were classified into: open water, emergent vegetation, shoreline, ridge, island, and dry pond or creek. The diameter of open water in the ponds (< 50 m, 50-150 m and > 150 m), general depth (estimated using the length of the crane’s legs that were observed in water), type and % of emergent vegetation namely: *Scirpus validus*; *Typha latifolia*; *and Carex* spp.; in the ponds the cranes were observed in were also recorded. Monthly habitat use patterns were compared for May, June, July, and August. At the fourth order scale specific food items were identified from whooping crane fecals and ground observations.

Diet Items

Whooping crane fecal samples were collected from the nesting area in WBNP over four consecutive summers (1996-1999, 1996 was a trial season prior to the main study). There were several obstacles in locating whooping crane fecals. First, due to the aquatic tendency of the whooping crane mo435st of the fecal samples could not be located as they are deposited in water. In addition, due to the presence of sandhill cranes throughout the whooping crane area only the collection of fecal samples along large (> 10 cm center toe) crane tracks were conducted. Two methods were employed to locate fecal samples. The first method involved walking shorelines and searching for large crane tracks on the exposed shorelines of the ponds in July and August. The second technique was to conduct aerial surveys in the evening and locate areas where family groups were roosting which was often on small islands in the ponds. These locations were investigated for fecal samples the following day. Nineteen fecal samples were collected in 1999, eight in 1998, eight in 1997 and 22 in 1996. The droppings collected were allowed to air dry in paper bags. The dried fecal samples were sorted and separated using a system based on the techniques described by Giles (1971). The fecal samples were put through different sizes of screening and different particle sizes were separated. Samples were divided into the following groups, snail shells, seeds, seed skin, insect parts, feathers, hair, bones (non-fish), teeth, fish bones, fish remains and unidentified. Identification was provided by various experts.

Foraging activity of adult cranes was recorded by direct observation from blinds. Plywood blinds were transported by helicopter and set up 70 m from 4 nest sites. The blinds’ dimensions were 120 cm by 120 cm in width and 195 cm in height with viewing ports on three sides. At the same time the blinds were put into place, the eggs were floated to determine fertility and to get an approximate hatching date. A camp was established 1000 m away from the nest pond and observation sessions in the blinds lasted from two to six hrs and continued for 2 weeks until the family group departed the nest pond. Information was recorded on feeding, and nesting behaviour of the adults and the chicks with the aid of a spotting scope (15 x 60 power) and binoculars (10 x 50 power).

Feeding Trials

In 1997 and 1998 experimental feeding trials were conducted at the Calgary Zoo. Fish, and invertebrates were transported from WBNP and were introduced into the pen of a pair of naive captive whooping cranes. Twelve each of brook stickleback (*Culea inconstans*) and dace spp.{(*Phoxinus eos* (Northern Red Belly dace), *Phoxinus neogaeus*, (Finescale dace) *Margariscus margarita* (Pearl dace) and their hybrids)} were place into a black rubber 60 liter tub (used as a water trough for the cranes) filled with 35 liters of water. In 1998, brook stickleback, dace spp., and invertebrates, {(sub-order Anisoptera (dragon fly) nymphs, *Dytiscidae* (diving beetles) small and large, *Lymnaeidae* (pond snail) and *Planorbidae* (wheel snail)} were transported to Calgary and placed into large plexiglass tubs (1 m by 1 m by 50 cm deep). Six of each brook stickleback, and dace spp. and 6 of each invertebrate taxa were placed in the tubs. The tubs were filled with 125 liters of water.

Pond Sampling

A minimum of three feeding and three random non feeding ponds were sampled for each nesting pair that was monitored. Where more than three known feeding ponds were within a territory, the ponds were numbered on an airphoto (up to 8) and the three ponds to be sampled were selected randomly. In an attempt to reduce site variability, the random non feeding ponds were selected close (within 500 m) to the feeding ponds. Once a feeding pond was selected for sampling 4 or 5 closest discrete (not connected by surface water to another water source) ponds were labeled 1 through 5. Using north as a starting point on the feeding pond the random non feeding ponds were labeled 1 through 5 clockwise for the first nest ponds sampled of the year and then the second nesting area had the random ponds labeled counterclockwise from the true north of the feeding pond and so on. Then the ponds to be sampled were selected randomly. There were 94 feeding and 94 random ponds sampled for a total of 188 ponds.

The individual ponds were sampled for the following: fish using 10 wire mesh “Gee” minnow traps; for aquatic invertebrates using plastic 2 liter pop bottle invertebrate traps (5 were used in 1997, 10 in 1998 and 1999); for snails using a 1.0 m^2 quadrat; and six small mammal tin cat traps were used on adjacent ridges to the ponds. In the ponds the fish and invertebrate traps were set in areas within the pond where the cranes were observed feeding generally within 5 m or in emergent vegetation or along the shorelines in enough water to cover the openings. The small mammal traps were set 3-5 m apart. Water parameters were measured, including: water depth (1 m and 5 m from shore and center of pond); pH; DO; conductivity; salinity; chlorophyll *a*; and total phosphorus. The colours of the ponds and type of emergent vegetation were recorded from the air. Water samples were collected from the center of ponds (or 25 m from shore on the large ponds > 150 m diameter) and were filtered through Whatman GF/C filters, which were then frozen until shipped for chlorophyll *a* analyses. Total phosphorus samples were treated with potassium persulfate and kept refrigerated until shipment for analyses. Samples were shipped to the University of Alberta, Meanook Biological Research Station for analysis within 10 days of sampling. In the ponds themselves, conductivity, temperature and salinity were measured using a YSI hand held meter while pH was measure with an Orion hand held meter.

Statistical Analysis

Habitat selection, usage, and comparisons of feeding (used) and random (non-used) ponds were analyzed with analysis of variance. The Chi-square test was used to compare habitat usage between years during the study. Mann-Whitney Rank Sum Test Statistic was used to analyze feeding vs randomly selected non feeding ponds.

Nesting pairs

Habitat use and behavior of all whooping cranes observed was recorded during the aerial surveys, in addition a more intensive monitoring regime was conducted on selected nesting pairs in the study area. The intensively monitored whooping crane pairs received a unique annual number according to when they were located during that particular year, in addition each of the pair's that were regularly monitored where given a letter for identification for classifying the pairs over the three years of the study (Table 4-1).

Table 4-1: Whooping crane nesting pairs intensively monitored.

Pair	Corresponding Annual Nest Numbers
A	(3-97, 3-98, 5-99)
B	(44-97, 6-99)
C	(4-98)
D	(15-97, 5-98, 7-99)
E	(5-97, 47-99)
F	(6-97, 8-98, 1-99)
G	(40-98)
H	(42-98, 8-99)

I	(18-98, 13-99)
J	(20-97, 15-98, 15-99)
K	(14-98, 16-99)
L	(23-97, 20-98, 37-99)
M	(39-97, 23-98, 11-99)

Results

Habitat Use and Foraging Ecology

A total of 2,479 habitat use locations (not including nest and flying whooping crane observations) were recorded from 148 aerial surveys conducted from 1997-1999 (Table 4-2).

Table 4-2: Number of aerial surveys conducted during the summer months, 1997-1999.

Month	**1997**	**1998**	**1999**	**Total**
April	0	0	3	3
May	4	6	9	19
June	35	10	21	66
July	8	11	11	30
August	3	12	12	27
September	0	3	0	3

Total	50	42	56	148

The majority of all the observations (73%) were of whooping cranes in open water or emergent vegetation in a pond. The remaining observations were of whooping cranes on shorelines, on ridges between the ponds, on islands in the ponds, or in dry ponds and creeks.

Third Order Selection Habitat Use

Overall, no significant difference in habitat use at the third order selection scale was identified between the three years (X^2 = 9.582, P = 0.296) (Tables 4-3 to 4-5). The general pattern of habitat use was open water and emergent vegetation used most frequently followed by shoreline, ridges, islands, dry ponds and creeks.

However, third order habitat use by whooping cranes differed significantly by month within all three years, 1997 (X^2 = 44.76, P = <0.001), 1998 (X^2 = 33.97, P=<0.001) and 1999 (X^2 = 69.49, P = <0.001). In 1997, emergent use was highest in June (44%), and then decreased throughout the summer, while open water use was lowest in June (32%), and then increased throughout the summer. Shoreline use increased throughout the summer, while ridge and island use were the highest during the month of June. Use of shoreline increased with each month, and the use of ridges being the highest in June. In 1998, emergent use was highest in June then declined as the summer progressed. Open water use was lowest in June and increased later in July and August. Little change was observed in monthly shoreline and ridge use. In 1999, emergent vegetation use was highest in June and then decreased throughout the summer months.

Open water use was again lowest in June and slightly increased in July then remained the same in August. Ridge and island use increased as the summer progressed. Over all three years, open water use was lowest in June and then increased through the summer months while emergent use was highest in June then decreased through the remaining summer months (Figure 4-1). No significant difference was detected in habitat use of individual whooping crane pairs (Table 4-6).

Table 4-3: Number of whooping cranes observed in different habitats during the summer months of 1997, in WBNP.

1997	*Nest		Emergent Vegetation		Open Water		Shore-line		Ridge		Island		Dry Pond		Creek		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
May	49	na	28	42	29	43	8	12	1	1	1	1	0	0	0	0	67
June	155	na	285	44	208	32	85	13	66	10	9	1	0	0	0	0	653
July	0	na	36	28	53	40	24	18	9	7	7	5	2	2	0	0	131
August	0	na	8	14	35	62	11	19	3	5	0	0	0	0	0	0	57
Total # **Mean (%)**	204	na	357	(39)	325	(36)	128	(14)	79	(9)	17	(2)	2	(0.2)	0	(0)	908

*Nest observations were not included in analysis

Table 4-4: Number of whooping cranes observed in different habitats during the summer months of 1998, in WBNP.

1998	*Nest		Emergent Vegetation		Open Water		Shore-line		Ridge		Island		Dry Pond		Creek		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	**#**
May	51	na	29	39	33	45	7	10	4	5	1	1	0	0	0	0	74
June	0	na	68	41	70	42	13	8	16	9	0	0	0	0	0	0	167
July	0	na	52	27	89	46	12	6	21	11	18	9	0	0	1	1	193
August	0	na	30	14	131	60	22	10	20	9	13	6	3	1	0	0	219
September	0	na	3	8	35	87	0	0	0	0	2	5	0	0	0	0	40
Total # **Mean (%)**	51	na	182	(26)	358	(52)	54	(8)	61	(8)	34	(5)	3	(.4)	1	(.1)	693

*Nest observations were not included in analysis

Table 4-5: Number of whooping cranes observed in different habitats during the summer months of 1999, in WBNP.

1999	*Nest		Emergent Vegetation		Open Water		Shore-line		Ridge		Island		Dry Pond		Creek		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%	**#**
April	4	na	15	35	19	44	6	14	2	5	1	2	0	0	0	0	43
May	81	na	10	11	51	59	14	16	4	5	2	2	4	5	2	2	87
June	18	na	137	47	95	32	22	8	30	10	8	3	0	0	0	0	292
July	0	na	61	27	83	36	27	12	40	17	17	7	0	0	1	.4	229
August	0	na	37	16	81	36	22	10	57	25	25	11	3	1	2	1	227
Total # **Mean (%)**	103	(na)	260	(30)	329	(37)	91	(10)	133	(15)	53	(6)	7	(1)	5	(1)	878

*Nest observations were not included in analysis

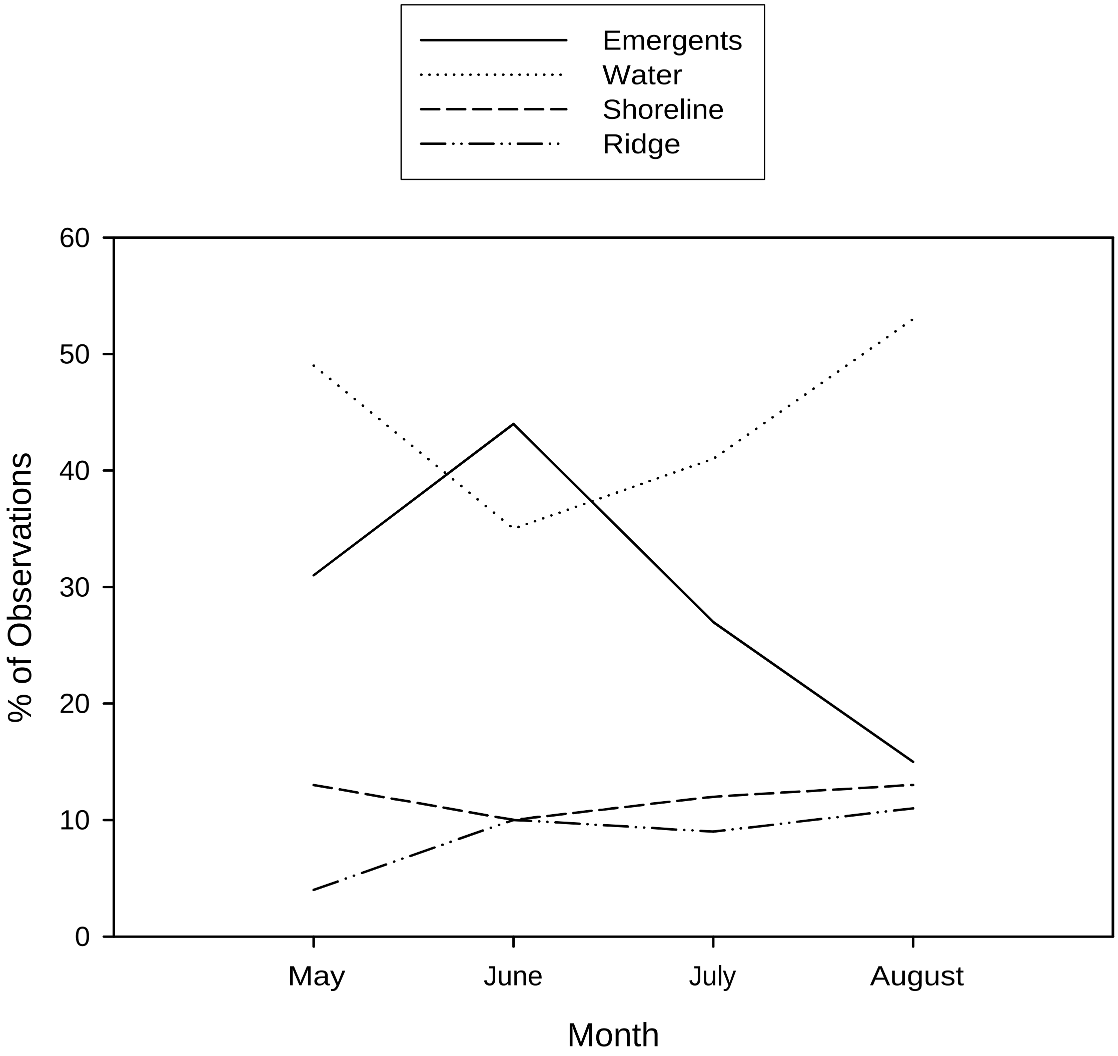

Figure 1: Whooping crane habitat use by month, 1997-1999.

Table 4-6: Habitat use of individual whooping crane pairs.

1997-1999	Emergent Vegetation		Open Water		Shore-line		Ridge		Island		Dry Pond		Creek		**Total**
Nesting Pair	#	%	#	%	#	%	#	%	#	%	#	%	#	%	**#**
A	113	62	38	21	17	9	10	5	6	3	0	0	0	0	184
B	79	46	47	28	16	9	28	16	2	1	0	0	0	0	172
C	11	33	17	52	2	6	3	9	0	0	0	0	0	0	33
D	92	48	63	33	17	9	10	5	9	5	0	0	0	0	191
E	39	31	60	47	4	3	16	13	8	6	0	0	0	0	127
F	57	27	101	47	16	8	22	10	16	7	2	1	0	0	214
G	18	36	26	52	0	0	2	4	2	4	2	4	0	0	50
H	15	23	22	35	2	3	15	23	7	11	3	5	0	0	64
I	27	22	45	37	24	20	21	18	4	3	0	0	0	0	121
J	41	27	44	29	21	14	40	25	8	5	0	0	0	0	154
K	29	46	21	33	4	6	9	15	0	0	0	0	0	0	63
L	50	26	79	41	29	15	19	10	14	7	1	1	0	0	192
M	49	26	76	40	29	15	27	14	10	5	0	0	0	0	191
Total # **Mean (%)**	620	(35)	639	(36)	181	(10)	222	(13)	86	(5)	8	(1)	0	(0)	1756

The majority (83%) of the ponds where whooping cranes were observed contained some type of emergent vegetation. Of the ponds with emergents, the cranes were observed in or close to ($\leq$ 5 m) to *Scirpus validus* (47%), in or close to *Carex* spp. (31%), and in or close to *Typha latifolia* (22%) in all three years (Tables 4-7 to 4-9). Habitat use was significantly different between the years (X^2 = 19.86, P = <0.001; Figure 2). The main difference between the years was *Typha latifolia* was used less and *Carex* spp.more in 1997. Individual nesting pairs use of emergent vegetation did not differ significantly (Table 4-10).

In all three years use of emergent vegetation between the summer months differed significantly (1997 X^2 = 51.54, P = <0.001; 1998 X^2 = 55.43, P = <0.001 and 1999 X^2 = 65.67, P = <0.001). In 1997, *Carex* spp. was used less in May and August than in June and July and *Scirpus validus* was used the most in May. *Scirpus validus* was used the most in May and August, in July, *Typha latifolia* was used more. In 1998, *Carex* spp. was used less in May and August than in other months. In 1999, *Scirpus validus* was used more and *Carex* spp. used less in May than other months. In June, *Scirpus validus* was used less and *Typha latifolia* used more. In August, the whooping cranes were observed more often in *Carex* spp. and less often in *Scirpus validus*.

Table 4-7: Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1997.

1997	*Scirpus Validus*		*Typha latifolia*		*Carex* spp.		**Total**
Month	#	%	#	%	#	%	#
May	18	67	4	15	5	18	27
June	140	49	32	11	115	40	287
July	11	31	2	6	22	63	35
August	5	63	1	12	2	25	8
Total # **Mean (%)**	174	(49)	39	(11)	144	(40)	357

Table 4-8: Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1998.

1998	*Scirpus Validus*		*Typha latifolia*		*Carex* spp.		**Total**
Month	#	%	#	%	#	%	#
May	19	61	8	26	4	13	31
June	20	33	19	31	22	36	61
July	17	30	29	52	10	18	56
August	19	65	6	21	4	14	29
Sept	3	60	0	0	2	40	5
Total # **Mean (%)**	78	(43)	62	(34)	42	(23)	182

Table 4-9: Emergent vegetation habitat use by whooping cranes in WBNP during the summer months of 1999.

1999	*Scirpus Validus*		*Typha latifolia*		*Carex* spp.		**Total**
Month	#	%	#	%	#	%	#
April	9	60	4	27	2	13	15
May	8	80	2	20	0	0	10
June	61	45	51	37	25	18	137
July	35	57	10	17	16	26	61
August	14	38	8	22	15	40	37
Total # **Mean(%)**	127	(49)	75	(29)	58	(22)	260

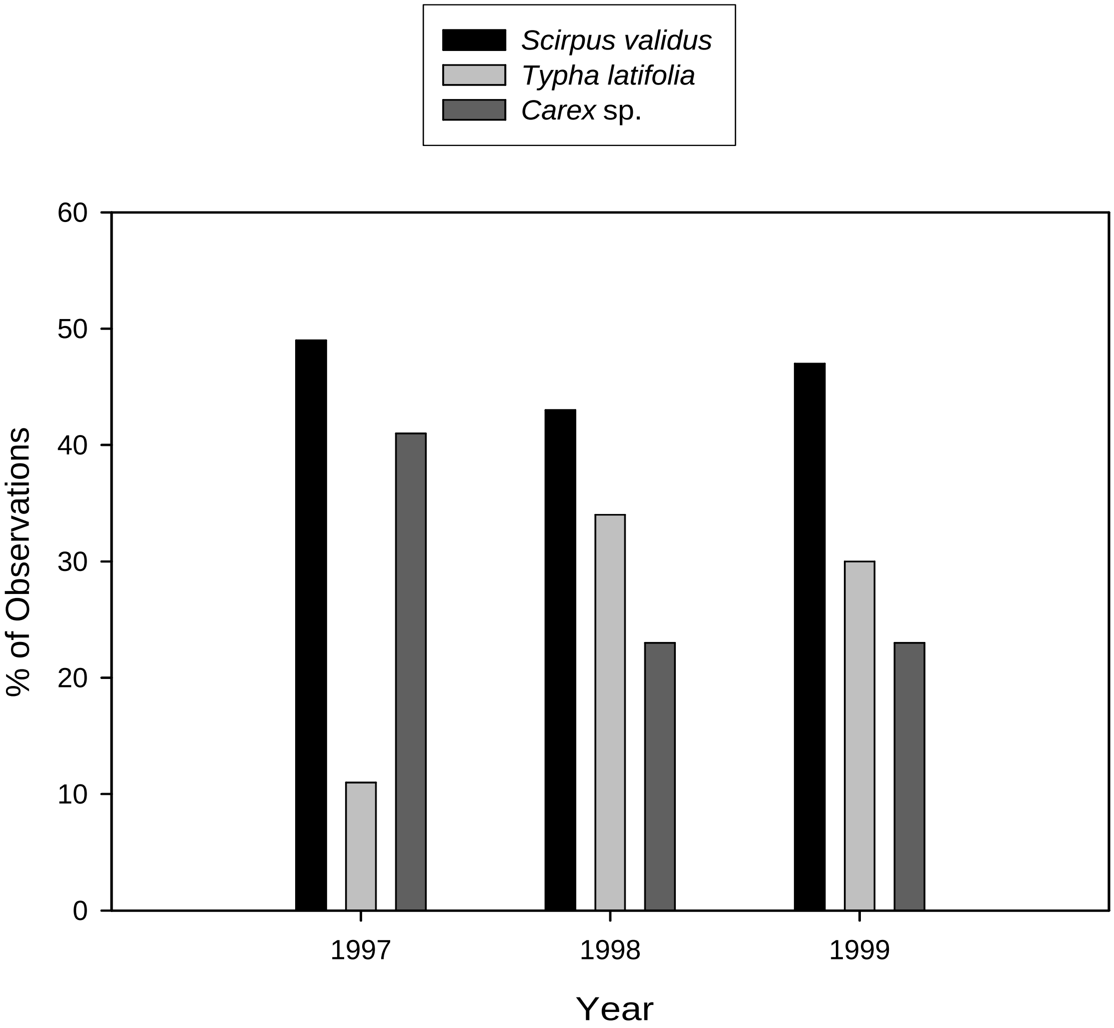

Figure 2: Emergent vegetation use by year, 1997-1999.

Table 4-10: Emergent vegetation habitat used by the individual whooping crane pairs.

1997-1999	*Scirpus Validus*		*Typha latifolia*		*Carex* spp.		**Total**
Nest Pair	#	%	#	%	#	%	#
A	19	17	29	26	65	57	113
B	36	46	25	31	18	23	79
C	3	27	8	73	0	0	11
D	19	20	41	45	32	35	92
E	13	33	6	16	20	51	39
F	28	49	20	35	9	16	57
G	4	22	10	56	4	22	18
H	10	66	1	7	4	27	15
I	22	81	2	8	3	11	27
J	30	73	3	7	8	20	41
K	10	35	16	55	3	10	29
L	38	76	1	2	11	22	50
M	25	51	7	14	17	35	49
Total # **Mean (%)**	257	(42)	169	(27)	194	(31)	620

There was a significant difference in the number of whooping cranes observed close to emergent vegetation ($\leq$ 5 m) between the three years ($X^2 = 12.25$, $P = 0.016$, Table 4-11). The largest differences were fewer observations close to *Typha latifolia* and more observation of whooping cranes close to *Carex* spp**.** in 1997, and fewer observations close to *Carex* spp**.** in 1999.

Table 4-11: Number of whooping cranes observed $\leq$ 5 m from three types of emergent vegetation in WBNP (1997-1999).

1997-1999	*Scirpus validus*		*Typha latifolia*		*Carex* spp.		**Total**
Year	#	%	#	%	#	%	#
1997	123	68	15	8	42	23	180
1998	146	64	45	20	36	16	227
1999	135	68	44	22	20	10	199
Total # **Mean (%)**	404	(67)	104	(17)	98	(16)	606

*****Nest observations were not included in analysis

Whooping cranes observed in dry vegetation were primarily found on ridges that were shrub-dominated (Table 4-12). The type of habitat used when cranes were observed on ridges did not differ between the three years, ($X^2 = 2.38$, $P = 0.304$). Whooping cranes used similar habitat types over the three years when observed out of ponds.

Table 4-12: Number of observations of whooping cranes on ridges in WBNP (1997-1999).

1997-1999	*Picea mariana* - *Larix laricina*		*Salix* spp.- *Betula glandulosa*		**Total**
Year	#	%	#	%	#
1997	20	25	59	75	79
1998	18	29	43	71	61
1999	46	35	87	65	133
Total # **Mean (%)**	84	(31)	189	(69)	273

The cranes were observed most often (80%) in ponds $\leq$ 150 m in diameter and (20%) in ponds > 150 m diameter. The proportional use of pond sizes did not differ between years (Tables 4-13 to 4-15).

In all three years, the size of open water habitats where the whooping cranes were observed differed significantly by month (1997 X^2 = 61.95, df = 6, P = <0.001, Table 4-13, 1998 X^2 = 118.11, df = 8P = <0.001, Table 4-14, and 1999 X^2 = 43.72, df = 8 P = <0.001, Table 4-15). In 1997, the small ponds (< 50) m were used significantly more and the medium (50-150 m) and large ponds (> 150 m) were used less in May while the larger ponds were used more than the smaller ponds in July, and August. In 1998, smaller ponds were used more in May and larger ponds used more in July. In 1999, May, small ponds were used less in May and large ponds used more in August.

Table 4-13: Number of whooping cranes observed in different sizes (diameter in m) of open water habitats in WBNP during 1997.

1997	< 50		50-150		> 150		**Total**
Month	#	%	#	%	#	%	#
May	18	75	6	25	0	0	24
June	95	49	63	33	35	18	193
July	19	33	21	36	18	31	58
August	16	32	24	48	10	20	50
Total # **Mean (%)**	148	(46)	114	(35)	63	(19)	325

Table 4-14: Number of whooping cranes observed in different sizes (diameter in m) of open water pond habitats in WBNP during 1998.

1998	< 50		50-150		> 150		**Total**
Month	#	%	#	%	#	%	#
May	13	57	9	39	1	4	23
June	57	81	13	19	0	0	70
July	45	49	17	18	31	33	93
August	83	63	27	20	22	17	132
Sept	8	20	19	48	13	32	40
Total # **Mean (%)**	206	(57)	85	(24)	67	(19)	358

Table 4-15: Number of whooping cranes observed in different sizes (diameter in m) of open water habitats in WBNP during 1999.

1999	< 50		50-150		> 150		**Total**
Month	#	%	#	%	#	%	#
April	3	25	7	58	2	17	12
May	19	37	27	53	5	10	51
June	49	51	32	33	15	16	96
July	34	39	30	35	22	26	86
August	25	29	29	35	30	36	84
Total # **Mean (%)**	130	(40)	125	(38)	74	(22)	329

There was no significant difference detected in initial activity of the whooping cranes in the ponds between the three years ($X^2 = 1.98$, P = 0.921). Eighty-eight percent of the initial observations of the cranes in ponds were feeding (probing) or standing (Table 4-16). No significant difference was detected in the initial activity of individual nesting pairs (Table 4-17).

Table 4-16: Initial activity of whooping cranes in ponds in WBNP, 1997-1999.

	Brood		Stand		Walk		Fly		Feed		**Total**
Year	#	%	#	%	#	%	#	%	#	%	
1997	11	1	382	42	68	8	2	0.2	447	49	910

1998	17	2	269	39	77	11	4	.5	330	47	697
1999	15	2	395	45	97	11	2	0.2	371	42	880
Totals # **Mean (%)**	43	(2)	1046	(42)	242	(10)	8	(0.3)	1148	(46)	2487

*Totals do not include incubation and flying observations. Totals do not match with habitat tables because for flying activity no specific habitat was identified.

Table 4-17: Initial activity of individual whooping crane pairs in ponds in WBNP, 1997-1999.

	Brood		Stand		Walk		Fly		Feed		**Total**
Nest Pair	#	%	#	%	#	%	#	%	#	%	
A	3	2	94	51	7	4	0	0	80	43	184
B	4	2	89	52	8	5	2	1	69	40	172
C	0	0	15	45.5	1	3	2	6	15	45.5	33
D	3	2	93	48	9	5	0	0	86	45	191
E	3	2	66	52	1	1	0	0	57	45	127
F	3	1	85	40	12	6	0	0	114	53	214
G	0	0	18	36	7	14	0	0	25	50	50
H	1	2	32	50	8	12	0	0	23	36	64
I	1	1	48	40	22	18	0	0	50	41	121
J	3	2	72	47	17	11	0	0	62	40	154
K	0	0	24	38	5	8	0	0	34	54	63
L	6	3	76	39	21	11	1	1	88	46	192
M	3	2	80	42	14	7	1	1	93	48	191
Totals # Mean (%)	30	(2)	792	(45)	132	(7)	6	(1)	796	(45)	1756

*Totals do not include incubation and flying observations. Totals do not match with habitat tables because for flying activity no specific habitat was identified.

Activity of Whooping Cranes

Initial activity observed on ridges and islands differed significantly between years (X^2 = 18.94, P = 0.004) (Table 4-18). The largest differences were for brooding observations which were more frequent and feeding was less in 1998 when compared with 1997 and 1999, and in 1997, feeding was higher than the other two years. The whooping cranes' initial activities differed significantly in pond habitats as compared with their activity on ridges/islands (X^2 = 43.22, P = <0.001). Feeding activity was more frequent in ponds than on ridges or islands. When the whooping cranes were observed on the ridges surrounding the ponds or on islands within the ponds, 70% and 15% of the cranes were standing or walking respectively and only 6% feeding (probing) (Table 4-18).

Table 4-18: Initial activity of whooping cranes on ridges/islands in WBNP, 1997-1999.

	Brood		Stand		Walk		Feed		
Year	#	%	#	%	#	%	#	%	**Total**
1997	5	5	67	70	13	14	11	11	96
1998	17	18	61	64	16	17	1	1	95
1999	13	7	134	72	28	15	11	6	186
Totals	35	(9)	262	(70)	57	(15)	23	(6)	377
Mean (%)									

*Totals do not include incubation and flying observations.

Over the three years initial activity varied during the summer months. In May, (X^2 = 13.8, P = 0.032), standing was observed more frequently in 1997 and 1999 but less in 1998 and walking activity was less in 1997 and walking more in 1998. For the months of June, July and August no significant difference was detected in activity between months.

Initial activity also varied significantly by month within years (Tables 4-19 to 4-21); 1997 at the p = 0.100 level, (X^2 = 10.9, P = 0.090); 1998 (X^2 = 25.2, P = <0.001); and 1999 (X^2 = 18.4, P = 0.005).

Table 4-19: Initial activity of whooping cranes in ponds by month in WBNP, 1997.

	Brood		Stand		Walk		Fly		Feed		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#
May	0	0	25	32	5	6	2	3	46	59	78
June	7	1	289	44	50	7	0	0	313	48	659
July	3	2	56	39	9	6	0	0	76	53	144
August	1	3	12	42	4	14	0	0	12	41	29
Totals # **Mean (%)**	11	(1)	382	(42)	68	(7)	2	(0.2)	447	(49)	910

Table 4-20: Initial activity of whooping cranes in ponds by month in WBNP, 1998.

	Brood		Stand		Walk		Fly		Feed		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#
May	2	2	16	16	17	17	4	4	60	61	99
June	0	0	87	47	16	8	0	0	83	45	186
July	8	4	90	44	17	8	0	0	90	44	205
August	7	3	76	37	27	13	0	0	97	47	207
Totals # Mean (%)	17	(2)	269	(39)	77	(11)	4	(0.5)	330	(47)	697

Table 4-21: Initial activity in ponds by month in WBNP, 1999.

	Brood		Stand		Walk		Fly		Feed		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#
May	1	0.6	46	29	14	9	2	1	93	60	156
June	5	2	126	45	25	9	0	0	124	44	280
July	5	2	107	50	28	13	0	0	76	35	216
August	4	2	116	51	30	13	0	0	78	34	228
Totals # **Mean (%)**	15	(2)	395	(45)	97	(11)	2	(0.2)	371	(42)	880

Feeding Observations

Whooping cranes were observed probing primarily in open water and in emergent vegetation which combined for 91% of all feeding observations (Figure 4-3). In 1997 and 1998 but not in 1999, the habitats where the canes were observed feeding was significantly different between months (respectively 1997 X^2 = 35.81, P = <0.001, Table 4-22, 1998 X^2 = 28.00, P = <0.001, Table 4-23, and 1999 X^2 = 2.60, P = 0.857, Table 4-24). In 1997, emergent vegetation was used less, and shorelines were used more in May. In June, emergent vegetation was used more. In August 1997, emergent vegetation was used less, open water habitat was used more and shorelines were used less.

Table 4-22: Habitat where whooping cranes were observed feeding in WBNP in 1997.

1997	Emergent Vegetation		Open water		Shoreline		Ridge		Island		Dry Pond		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	#
May	7	22	19	59	5	16	1	3	0	0	0	0	32

June	137	46	117	40	35	12	6	2	1	.3	0	0	296
July	24	28	51	59	9	10	2	2	1	1	0	0	87
August	5	16	25	78	2	6	0	0	0	0	0	0	32
Total **Mean %**	173	(39)	212	(47)	51	(11)	9	(2)	2	(.4)	0	0	447

In 1998, ridge and island habitats and habitat use in the month of September were not used in the analysis as there were too few observations. Emergent vegetation was used more in May and June and less in July and August. Open water was used less in May and June and more in July and August.

Table 4-23: Habitat where whooping cranes were observed feeding in WBNP in 1998.

1998	Emergent Vegetation		Open water		Shoreline		Ridge		Island		Dry Pond		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	**#**
May	12	30	24	60	4	10	0	0	0	0	0	0	40
June	24	30	53	65	3	4	1	1	0	0	0	0	81
July	14	17	70	83	0	0	0	0	0	0	0	0	84
August	15	15	81	83	1	1	0	0	0	0	1	1	98
Sept	1	4	26	96	0	0	0	0	0	0	0	0	27
Total # **Mean (%)**	66	(20)	254	(77)	8	(2)	1	(.3)	0	(0)	1	(.3)	330

Table 4-24: Habitat where whooping cranes were observed feeding in WBNP in 1999.

1999	Emergent Vegetation		Open water		Shoreline		Ridge		Island		Dry Pond		**Total**
Month	#	%	#	%	#	%	#	%	#	%	#	%	#
April	9	35	15	58	2	7	0	0	0	0	0	0	26
May	16	27	37	63	3	5	0	0	0	0	3	5	59
June	39	30	75	58	10	8	5	4	0	0	0	0	129
July	24	30	48	61	3	4	3	4	1	1	0	0	79
August	20	26	51	66	4	5	1	1	1	1	1	1	78
Total # **Mean (%)**	108	(29)	226	(61)	22	(6)	9	(2)	2	(1)	4	(1)	371

While feeding in or close ($\leq$ 5 m) to emergent vegetation the whooping cranes were associated with *Scirpus validus* 58%, *Carex* spp. 26%, and *Typha latifolia* 21% of the time (Tables 4-25 and 4-26). The number of observations of whooping cranes feeding in types of emergent vegetation differed between the three years (X^2 = 30.66, P = <0.001). In 1997, *Typha latifolia* was used less and *Carex* spp. more. In 1998, *Typha latifolia* was used more and *Carex* spp. was used proportionately less. In 1999, *Carex* spp. was used less by the whooping cranes. No significant difference was detected in feeding patterns of selected nesting pairs (Table 4-27 and 4-28).

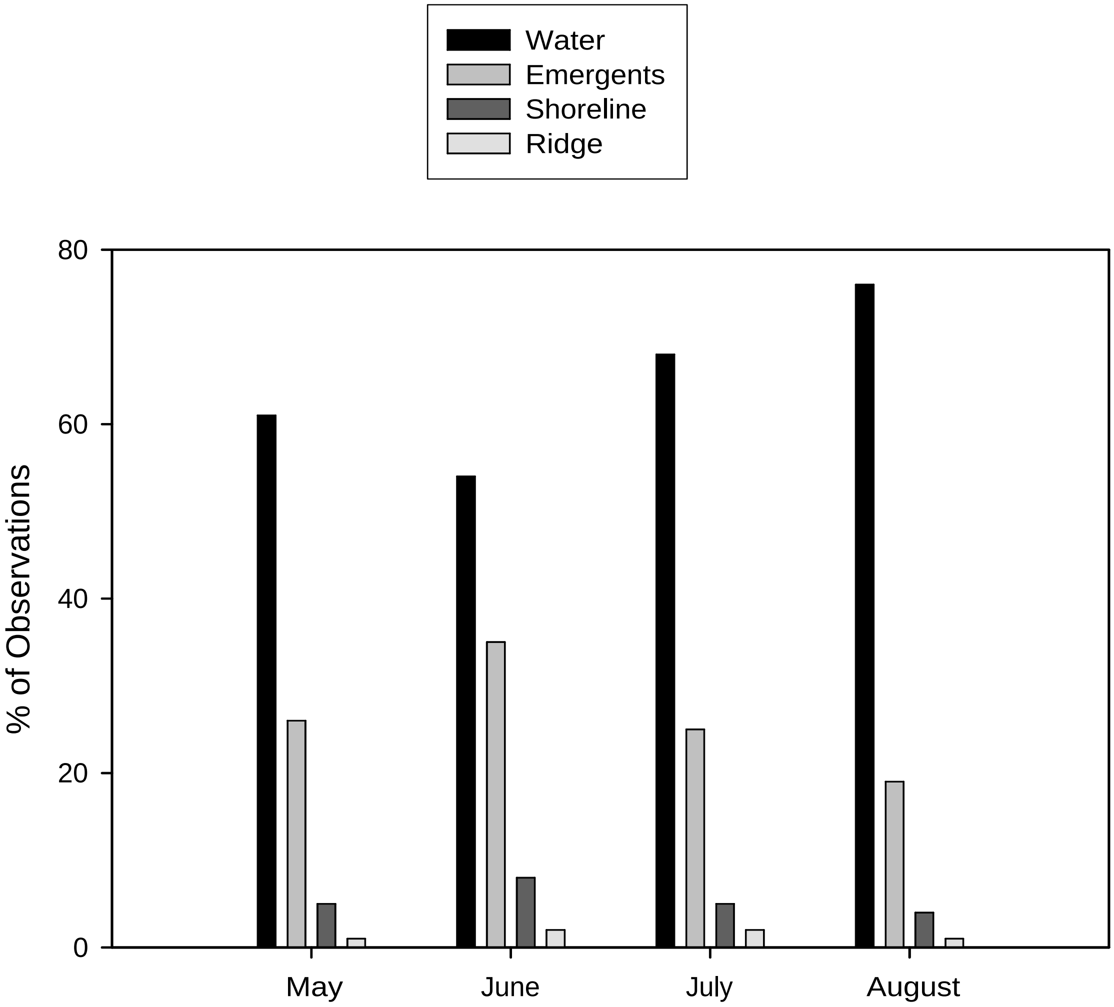

Figure 3: Habitat used for feeding, 1997-1999.

Table 4-25: Number of observations of whooping cranes feeding in emergent vegetation in WBNP (1997-1999).

1997-1999	*Scirpus validus*		*Typha latifolia*		*Carex* spp.		**Total**
Year	#	%	#	%	#	%	#
1997	80	46	21	12	72	42	173
1998	32	48	25	38	9	14	66
1999	55	51	31	29	22	20	108
Total # **Mean (%)**	167	(48)	77	(22)	103	(30)	347

Feeding observations close to emergent vegetation varied significantly between years (X^2 = 16.57, P = 0.002) (Table 4-26). Feeding close to *Scirpus validus* did not vary between years however the whooping cranes fed close to *Typha latifolia* more in 1998 and 1999 and fed close to *Carex* spp. more often in 1997.

Table 4-26: Number of whooping cranes observed feeding $\leq$ 5 m from emergent vegetation in WBNP (1997-1999).

1997-1999	*Scirpus validus*		*Typha latifolia*		*Carex* spp.		**Total**
Year	#	%	#	%	#	%	#
1997	120	66	20	11	42	23	182
1998	90	67	29	22	15	11	134
1999	99	63	43	28	14	9	156
Total **Mean (%)**	309	(66)	92	(20)	71	(14)	472

Table: 4-27 Habitat where individual pairs of whooping cranes were observed feeding.

1997-1999	Emergent Vegetation		Open water		Shoreline		Ridge		Island		Dry Pond		**Total**
Nest Pair	#	%	#	%	#	%	#	%	#	%	#	%	**#**
A	53	66	26	33	1	1	0	0	0	0	0	0	80
B	33	48	28	41	6	9	1	1	1	1	0	0	69
C	3	20	12	80	0	0	0	0	0	0	0	0	15
D	39	45	40	47	6	7	1	1	0	0	0	0	86
E	16	28	38	67	1	2	0	0	2	3	0	0	57
F	23	20	76	67	10	9	4	3	1	1	0	0	114
G	5	20	20	80	0	0	0	0	0	0	0	0	25
H	7	31	14	61	1	4	0	0	0	0	1	4	23
I	11	22	30	60	6	12	3	6	0	0	0	0	50
J	21	34	32	51	6	10	3	5	0	0	0	0	62
K	17	50	17	50	0	0	0	0	0	0	0	0	34
L	20	23	48	55	19	21	0	0	0	0	1	1	88
M	21	23	57	61	14	15	1	1	0	0	0	0	93
Total **Mean (%)**	269	(33)	438	(55)	70	(9)	13	(2)	4	(1)	2	(0.2)	796

Table 4-28: Type of emergent vegetation habitat used for feeding by individual pairs of whooping cranes.

1997-1999	*Scirpus validus*		*Typha latifolia*		*Carex* spp.		**Total**
Nest Pair	#	%	#	%	#	%	#
A	10	19	10	19	33	62	53
B	20	61	10	30	3	9	33
C	3	100	0	0	0	0	3
D	6	15	21	54	12	31	39
E	3	18	2	13	11	69	16
F	12	52	9	39	2	9	23
G	1	20	4	80	0	0	5
H	6	86	1	14	0	0	7
I	8	73	2	18	1	9	11
J	17	81	0	0	4	19	21
K	7	41	10	59	0	0	17
L	16	80	1	5	3	15	20
M	13	62	7	33	1	5	21
Total # **Mean (%)**	122	(45)	77	(29)	70	(26)	269

No significant difference was detected in color of ponds used by whooping cranes between the three years. The cranes were observed feeding in light-dark brown ponds (87%) most often (Table 4-29).

Table 4-29: Color of ponds where the cranes were observed feeding

1997-1999	Black		Dark Brown		Light Brown		Grey-Pink		**Total**
Year	#	%	#	%	#	%	#	%	#
1997	16	4	104	27	248	64	17	5	385
1998	23	7	98	31	161	50	38	12	320
1999	31	9	133	40	144	43	26	8	334
Total **Mean (%)**	70	(7)	335	(32)	553	(53)	81	(8)	1039

The majority (83%) of the feeding observations were of cranes probing in shallow water which was below their tibiotarsal-tarsometatarsal joint (approx. $\leq$ 35 cm) and 8% were in deeper water above the joint (approx. >35 cm) and only 9% of the feeding observations were in dry areas. The approximate water depths that the cranes were observed feeding in differed from year to year ($X^2 = 11.08$, P = 0.026, Table 4-30). Dry areas were used more in 1997 and 1999, shallow waters ($\leq$ 35 cm) were used more in 1998 and deeper ponds (> 35 cm) were used more in 1999. No significant difference was detected in water depths where individual nesting pairs were observed feeding (Table 4-30).

Table 4-30: Approximate water depths where whooping cranes were observed feeding.

1997-1999	Dry		≤ 35 cm		> 35 cm		**Total**
Year	#	%	#	%	#	%	#
1997	62	14	363	81	22	5	447
1998	10	3	296	90	24	7	330
1999	37	10	291	78	43	12	371
Total # **Mean (%)**	109	(9)	950	(83)	89	(8)	1148

Table 4-31: Approximate water depth where individual selected pairs of whooping cranes were observed feeding.

1997-1999	Dry	< 35 cm	> 35 cm	**Total**

Nest Pair	#	%	#	%	#	%	#
A	1	1	62	78	17	21	80
B	8	12	55	79	6	9	69
C	0	0	7	47	8	53	15
D	7	8	72	84	7	8	86
E	3	5	44	77	10	18	57
F	15	13	82	72	17	15	114
G	0	0	18	72	7	28	25
H	2	9	15	65	6	26	23
I	9	18	33	66	8	16	50
J	11	18	39	63	12	19	62
K	0	0	26	76	8	24	34
L	20	23	59	67	9	10	88
M	15	16	71	76	7	8	93
Total # **Mean (%)**	91	(12)	583	(73)	122	(15)	796

Fourth Order Habitat Selection

Whooping cranes in WBNP have a varied diet including: snails *(Probbythinella* *lacrustis*), brook stickleback, (*Culea inconstans*), northern redbelly dace (*Phoxinus eos*), pearl dace (*Margariscus margarita*), finescale dace (*Phoxinus neogaeus*) and their hybrids, fathead minnows (*Pimephales promelas*), Anisoptera nymphs (including: *Aeshna* spp.; and *Libellula* spp.), Dytiscidae (including: *Graphoderus occidentalis; Acilius semisulcatus; Rhantus binotatus;* and *Dytiscus alaskanus*), spiked water milfoil (*Myriophyllum* spp.) and pond weed (*Potamogeton* spp.) (Tables 4-32 to 4-34). Number of occurrences refers to the number of fecal samples with the food item (e.g. 47 fecal samples had one or more seeds in them), % occurrences refers to the proportion of samples with that item out of the total of fecal samples (e.g. 82% of all the fecal samples contained seeds).

Table 4-32: Summary of food items found in whooping crane fecals (1996-1999).

Food Item	Number of occurrences	% occurrences (n=57)
Seeds	47	82
Snail shells	45	79
Insect parts	44	77
Fish bones	28	49
Feathers	13	23
Bones (non-fish)	9	16
Hair	3	5
Teeth	2	4

Table 4-33: Seeds found in 47 whooping crane fecals that contained seeds, 1996-1999.

Seed	Number of fecal samples (n=47)	Mean # of seeds per fecal sample
Carex aquatilis	1	1
Carex diandra	2	1
Potamogeton spp.	11	2
Myriophyllum spp.	24	80
Nuphar variegatum	3	11
Scirpus validus	2	1
Calamagrostis inexpansa	1	1
Calla palustris	1	1
Rorippa paulustris	1	10
Unknown	1	na

Table 4-34: Insect parts in 44 whooping crane fecal samples that contained insect parts, 1996-1999. Some fecal samples had more than one insect type.

Insect Parts	Number of fecal samples	Larvae	Adults
Anisoptera	22	20	2
Dytiscidae	26	6	20
Corixidae	9	0	9
Plecoptera	6	6	0

Diptera	6	0	6
Gastropoda	4	0	4
Notonectidae	2	0	2

Table 4-35: Comparison of insect parts in 22 whooping crane fecals between 1996 and 1999. Some fecals had more than one insect type.

Insect Parts **1996 and 1999**	Number of fecal samples that contained insect taxa		%	
	1996	1999	1996	1999
Anisoptera	8	11	32	31
Dytiscidae	8	11	32	31
Corixidae	5	3	20	8
Plecoptera	2	4	8	11
Diptera	2	4	8	11
Gastropoda	na	3	na	8

No statistical difference was detected between 1996 and 1999 in the number and type of insect parts in fecal samples (one way ANOVA P=1.00).

Ground Observations

The following food items were observed from blinds caught and consumed by adult whooping cranes and/or their young at nest sites. Anisoptera nymphs, Anisoptera adults, fish, Gastropoda, Hemiptera, Coleoptera, Lestidae, a Ranidae and *Clethrionmys* spp. Anisoptera nymphs were the most common (41%) followed by fish (18%) and

Gastropoda (18%). Due to the small sample size the results are to be taken cautiously (e.g. only one out of the four nest ponds where nest site observations occurred contained fish, based on sampling of the ponds post nesting). In addition, observations of adults feeding in the nest ponds were limited as the adults often did not feed in the nest pond and would fly off (presumably at least part of the time to feed) for up to 240 minutes at a time (n = 25, mean = 120 minutes, SE = 11.9). During periods of exchange at the nest site for alternating incubation duties little time was spent with both adults at the nest pond (n = 24, mean = 15.4 minutes, SE = 3.1).

Feeding Trials

In 1997, a captive pair of whooping cranes at the Calgary Zoo were offered live fish in their pen. Once they began to probe into the tub after 120 minutes of investigating the feeding tub, they were able to easily capture and eat all 24 fish within 10 minutes. In subsequent feeding trials in 1997 the cranes were able to capture and consume all 24 fish in less than 5 minutes once they began probing after 10 minutes of investigating the feeding tub. In 1998, when the same captive pair of whooping cranes was offered live fish and invertebrates, the cranes captured and ate primarily large diving beetles Dytiscidae (46%), and brook stickleback *Culaea inconstans* (35%) which accounted for over 80% of the items eaten over the 9 feeding trails (Table 4-36).

Table 4-36: Feeding trials at the Calgary Zoo, 1998.

Food Item	Number Eaten	Number killed
Dytiscidae (> 2 cm)	12	10

Culaea inconstans	9	10
Anisoptera	2	3
Dace spp.	0	2
Dytiscidae(< 2 cm)	1	7
Lymnaeidae	1	1
Planorbidae	1	2
Totals	26	35

Pond Sampling

In total, 188 ponds were sampled, for various environmental variables, fish, amphibians, and invertebrates (Figures 4-6). These ponds, including 94 ponds where the cranes were observed feeding and 94 randomly selected ponds where the cranes were not observed feeding. The ponds were sampled, in May, 3 ponds (2%), in June, 6 ponds (3%), in July, 91 ponds (48%), in August, 71 ponds (38%), and in September, 17 ponds (9%). Results from pond sampling (Tables 4-37 to 4-45) can be found in Appendix 1. Compared to randomly selected ponds (using Mann-Whitney Rank Sum Test Statistic), ponds where whooping cranes were observed feeding were significantly deeper 1m from shore ($P = 0.003$), 5m from shore ($P = <0.001$), and in the center of pond ($P = <0.001$), colder water temperature ($P = <0.001$), larger area ($P = 0.012$); greater perimeter ($P = <0.001$), less amount of exposed shoreline ($P = 0.007$), closer to surface creeks/streams ($P = 0.034$), more total emergent vegetation ($P = <0.001$), more *Scirpus validus* ($P = <0.001$), and *Typha latifolia* ($P = 0.015$); less DO ($P = 0.015$); less pH ($P = <0.001$). There was marginally less total phosphorous ($P = 0.070$) in feeding ponds (using $p = 0.10$). Minnow traps in feeding ponds caught significantly more stickleback (*Culaea inconstans*) ($P = <0.001$), Dace spp. ($P = <0.001$), and Planorbidae ($P = 0.015$), and significantly less Dytiscidae ($P = 0.003$), and Lymnaeidae ($P = 0.026$) than in random ponds. Invertebrate/activity traps in feeding ponds caught significantly more stickleback (*Culaea inconstans*) ($P = <0.001$), and Dace spp. ($P = 0.015$), than those in random ponds. In the quadrat sampling for gastropoda, no significant difference was detected between feeding and randomly selected ponds.

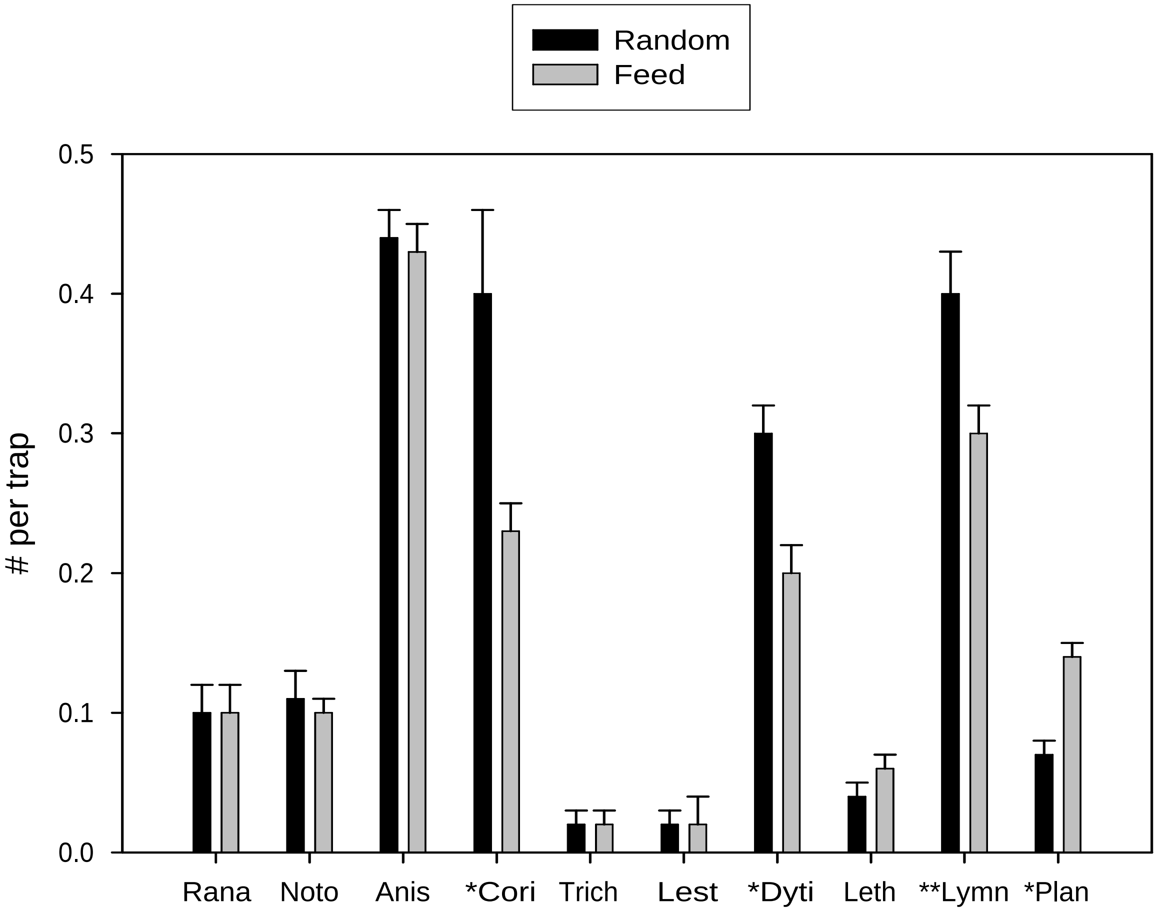

Figure 4: Relative Abundance (SE) of amphibian and major invertebrate taxa in 94 random ponds and 94 feeding ponds (* P = <0.05, ** P = <0.10).

Key for Figure 4 graph

Rana = Ranadae, Noto = Notonectidae, Anis = Anisoptera, Cori = Corixidae, Trich = Trichoptera, Lest = Lestidae, Dyti = Dytiscidae, Leth = *Lethocerus* sp., Lymn = Lymnaeidae, Plan = Planorbidae.

Emergent Vegetation

Of the 188 ponds sampled, 166 ponds contained emergent vegetation, 22 had none. *Scirpus validus* was present in 132 (70%) ponds, *Carex* spp. was found in 72 (38%) ponds and *Typha latifolia* was found in 45 (24%) ponds with several ponds containing more than one emergent vegetation type. Ponds that contained emergent vegetation were significantly deeper (P = 0.008) than ponds without emergent vegetation (24.6 cm SE = 1.9 vs 32.4 SE = 1.1). Ponds with *Typha latifolia* were significantly deeper (P = 0.003) than ponds without *Typha latifolia* and ponds that contained *Scirpus validus* and *Carex* spp. were marginally deeper (P = 0.073) and (P = 0.085) respectively, than ponds without *Scirpus validus* and *Carex* spp. (using p=0.10).

Fish

In total, fish were caught in 103 ponds. In randomly selected ponds, fish were caught in 31 ponds (33%), and not caught in 63 (67%) ponds; whereas in feeding ponds, fish were caught in 72 (77%) of the sampled ponds and were not caught in 22 (23%) of the ponds. Significantly more feeding ponds contained fish (P = <0.001) than random ponds (Mann-Whitney Rank Sum Test Statistic). Environmental variables differed between ponds where fish were caught and ponds where fish were not caught (Figure 5). The ponds where fish were caught were significantly deeper 1m from shore (P = <0.001), 5m from shore (P = <0.001) and center of pond (P = <0.001), colder (P = 0.026), closer to surface creeks/streams (P = 0.010), more *Scirpus validus* (P = <0.001) and *Carex* spp.(P = 0.049), more total emergent vegetation (P = <0.001), less DO (P = 0.004), lower pH (P = <0.001), and lower levels of total phosphorus (P =

0.045). Ponds where fish were caught had marginally: larger perimeters (P = 0.064); less exposed shoreline (P = 0.078); more *Typha latifolia* (P = 0.077); and higher salinity (P = 0.065) than ponds with no fish. In ponds where fish were caught in the minnow traps there were significantly fewer Corixidae (P = <0.001), Anisoptera (P = <0.001), Dytiscidae (P = <0.001), and Lymnaeidae (P = <0.001). In ponds where fish were caught in the invertebrate/activity traps there were significantly fewer Corixidae (P = <0.001) captured.

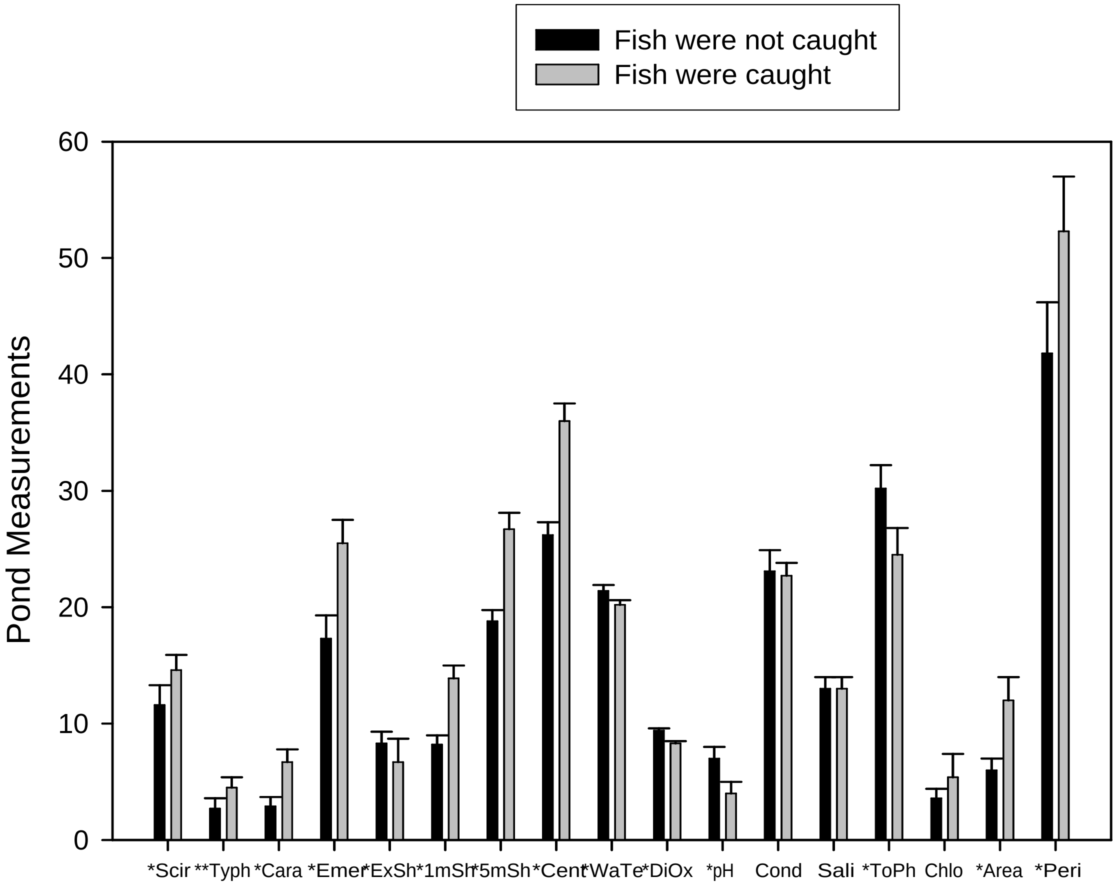

Figure 5: Pond variables where fish were caught and where no fish were caught (* P = <0.05, ** P = <0.10).

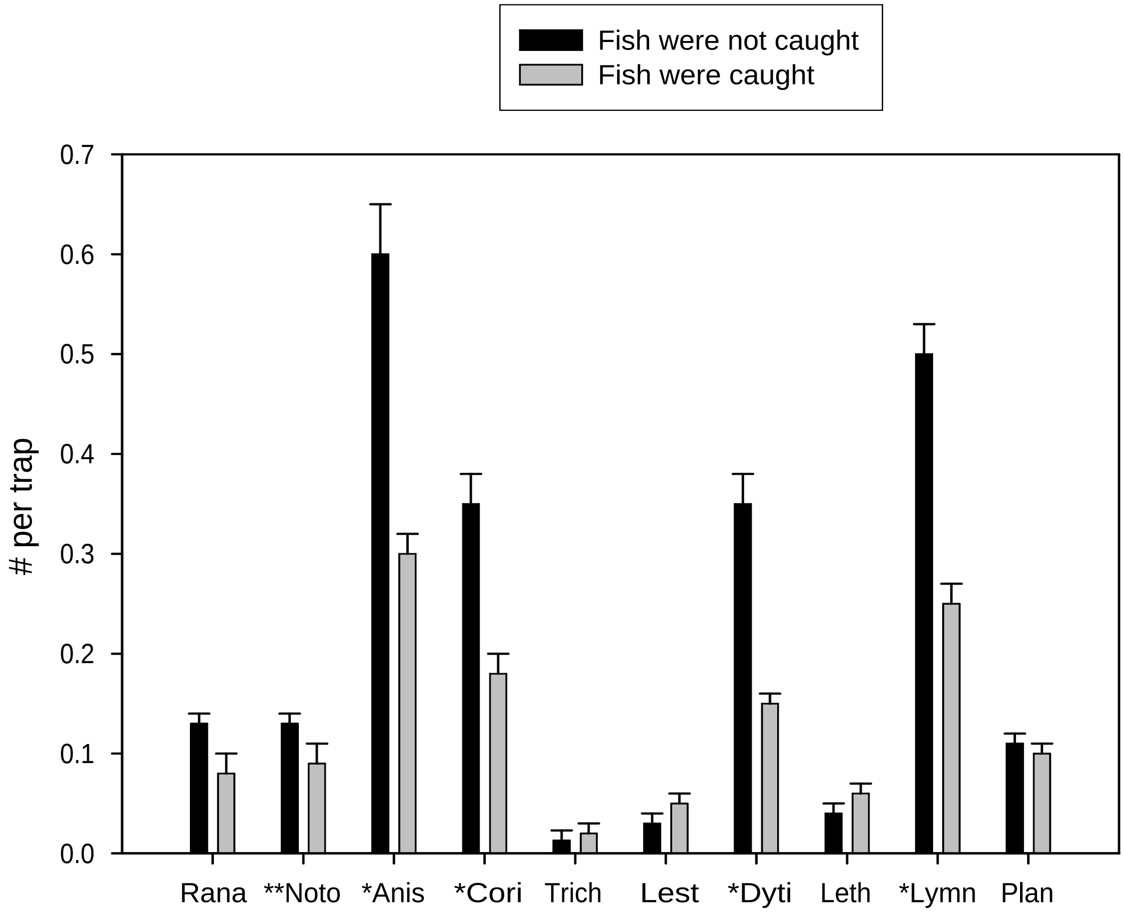

Figure 6: Relative Abundance (SE) of amphibians and major invertebrate taxa in 85 ponds with fish and 103 ponds where fish were not caught (* P = <0.05, ** P = <0.10).

A significant difference was detected in the amount of fish caught per trap night between the 3 years (One way ANOVA using Tukey's Test Statistic, P = .045, Table 4-46).

Table 4-46: Fish caught per trap night.

Year	Mean/trap night	SE
1997	11.9	3.1
1998	8.8	2.6
1999	3.0	1.1

No significant difference was detected between the amount of invertebrates caught per trap night between the three years (One way ANOVA using Tukey's Test Statistic P = 0.109, Table 4-47).

Table 4-47: Invertebrates caught per trap night.

Year	Mean/trap night	SE
1997	1.2	0.2
1998	1.8	0.9
1999	1.3	0.7

Distance to Creeks

Ponds where the whooping canes were observed feeding had a mean distance from a creek of 369 m (n = 94, SE = 40.8) which was significantly closer (P = 0.034, Mann-Whitney Rank Sum Test Statistic) than randomly selected ponds which had a mean distance of 436 m from a creek (n = 94, SE = 37.4). Ponds without emergent vegetation had a mean distance to creeks of 694 m, (n = 23, SE = 91.4) which was significantly closer (P = 0.007) than ponds with emergent vegetation which had a mean distance of 456 m from creeks (n = 165 , SE = 35.5). Ponds that were deeper (> 35 cm at center, n = 61, 426.1 m, SE = 62.7) were significantly closer to creeks than ponds that were shallower (n = 127, 507.7 m, SE = 38.7, P = 0.030). Ponds that contained fish were significantly closer to creeks (P = 0.010) than those where fish were not caught.

Core Nesting Area vs Periphery Areas

Productivity (fledged young/nest) did not differ between core and periphery nesting areas (t-test statistic P = 0.512, Table 4-48). Core areas were defined as the nesting area in the center of the range along the Sass-Klewi Rivers and the periphery areas were Nyarling and Alberta areas.

Table 4-48: Comparison of productivity of ponds with number of young produced per nesting pair.

Nest Pair	# of Ponds Sampled	Total Fish	Total trap Night	Ave. Fish per Trap Night	Total Invert	Avg. Invert per Trap Night	Total	Average Fish and Invert per TrapNight	# Fish ponds	Tadpole	Small mammals	ChicksFledged (%year)
A	18	2029	450.0	4.5	906.0	2.0	2935	6.5	5	12	1	2 (3) = 67
B	15	16	255.0	0.1	663.0	2.6	679	2.7	2	0	8	2 (2) = 100
C	6	201	120.0	0.6	563.0	4.7	764	6.4	3	1	0	0 (2) = 0
D	18	6328	330.0	19.2	253.0	0.8	6581	19.9	10	27	12	1 (3) = 33
E	12	1754	210.0	8.4	234.0	1.1	1988	9.5	8	208	3	1 (2) = 50
K	9	0	180.0	0.0	587.0	3.3	587	3.3	0	14	3	1 (1)=100
Total Periphery	**78**	**10328**	**1545.0**	**6.7**	**3206.0**	**2.1**	**13534**	**8.8**	**28**	**262**	**27**	**7 (13) = 54**
F	17	1593	315.0	5.1	324.0	1.0	1917	6.1	9	49	8	3 (3) = 100
G	6	1363	120.0	11.3	268.0	2.2	1631	13.6	6	25	10	0 (1) = 0
H	12	2170	240.0	9.0	544.0	2.3	2714	11.3	8	0	4	2 (2) = 100
I	16	2806	320.0	8.8	168.0	0.5	2974	9.3	14	4	5	1 (2) = 50
J	20	823	480.0	1.7	613.0	1.3	1436	2.9	11	1	26	2 (3) = 67
L	18	1724	330.0	5.2	407.0	1.2	2131	6.5	12	0	4	4 (3) = 1.33
M	21	4999	375.0	13.3	279.0	0.7	5278	14.1	15	33	1	2 (3) = 67
Total Core	**110**	**15478**	**2180.0**	**7.1**	**2603.0**	**1.2**	**18081**	**8.3**	**75**	**112**	**58**	**14 (17) = 82**

Gastropoda numbers using quadrat sampling was not used in analysis.

There were slightly more young fledged in the core nesting area for the nesting pairs that were monitored over all three years (at the p = 0.100 level, P = 0.064, t-test statistic) than in peripheral areas. The percentage of nesting pairs that fledged young per nesting attempt between 1997-1999 in the core area was 83% (SE = 10.8) compared to 56% for pairs on the periphery (SE = 14.1) (Table 4-49).

Table 4-49: Percentage of fledged young per nesting pair in periphery and core nesting areas in WBNP, 1997-1999.

Nest Pair	**Young/Year**	**% Fledged**
Periphery		
A	(2/3)	67
B	(2/2)	100
C	(0/2)	0
D	(1/3)	33
E	(2/3)	67
K	(2/3)	67
Core		
F	(3/3)	100
G	(1/2)	50
H	(3/3)	100
I	(2/3)	67
J	(2/3)	67
L	(4/3)	133
M	(2/3)	67

Although no significant correlation could be detected between water levels and productivity 1997 was the most productive and the ponds were the deepest (Table 4-50).

Table 4-50: Water levels as measured in center of ponds (cm) and reproductive success as measured in fledged young/nest.

Year	n	Mean Water Depth	SE	n	Mean Productivity	SE
1997	55	37	2.4	8	1.13	0.1
1998	73	30	1.4	11	0.64	0.2
1999	60	29	1.3	11	0.64	0.2

Comparing number of fish caught in territories of nesting pairs (n = 6) that had their ponds sampled for 3 consecutive summers. A difference was detected (P = 0.019, Kruskal-Wallis test statistic), with fewer fish being caught in1999 (Table 4-51).

Table 4-51: Fish caught in whooping crane territories of pair's monitored for 3 consecutive summers.

1997

Fish	# Traps with fish	Mean/trap	SE
Culaea inconstans	212	16.5	1.6
Dace spp.	120	32.5	4.3
Pimephales promelas	29	4.8	0.8

1998

Fish	# Traps with fish	Mean/trap	SE
Culaea inconstans	184	26.6	2.7
Dace spp.	98	20.6	3.8
Pimephales promelas	19	3.0	0.5

1999

Fish	# Traps with fish	Mean/trap	SE

Culaea inconstans	70	8.8	1.1
Dace spp.	60	27.9	2.9
Pimephales promelas	14	2.6	0.6

Discussion

Foraging Ecology

The use of food resources in avian species is determined primarily by morphology, physiology, and behavior patterns (Wiens 1989). External constraints associated with the use of resources also plays an important role and factors such as availability and distribution of the food resource, spatial and temporal attributes of the food resources used and competition with other species for the same resource (Wiens 1989). The acquisition of food items plays a prominent role in dictating a birds’s use of space and time (Hutto 1985). Changes in habitat patterns over time occur most frequently when resource levels change substantially (Wiens 1989). When a species uses a habitat dis-proportionately to availability that habitat type is inferred to be important (Manly et al. 1993). One method of detecting habitat selection is to compare occupied vs unoccupied habitats at similar spatial scales within a species range (Pereira and Itami 1991). This technique avoids the problems associated with defining available habitat. Foraging behaviors of animals rarely occur at random, even for generalists (Schaefer and Messier 1995b). Resource distribution and abundance, the time required to handle a prey type, the possibility of searching while handling prey, the digestible energy that can be extracted from a given prey, the time required to digest prey, the maximum amount of a resource that can be consumed during a day are all factors that have been used in optimal foraging models (Fryxell 1991). Variation in prey abundance should lead to an adjustment in patch residence time and not to a change in diet selection. The need for favorable microclimates, avoidance of predators and relief from insects can also influence foraging decisions (Schaeffer and Messier 1995a, Conradt et al. 2000), which complicate predictions from foraging optimality principles.

On the breeding grounds in WBNP whooping cranes have to balance their time and activity budgets between breeding, nesting, defending their territory, rearing of young with their own individual energetic requirements. Both biotic (distribution of food, predators) and abiotic (weather, water levels) factors play a role in the success or failure of raising young each year.

Third Order Habitat Selection

This study is the first to identify and describe in detail whooping crane third order habitat selection on their nesting grounds. Whooping cranes do not feed randomly across their nesting pond complex but are found in ponds that are deeper, colder, closer to creeks, and contain more emergent vegetation than randomly selected ponds. All of these variables are likely linked to the flooding component associated with distance to creeks. Intuitively ponds that are closer to a creek or stream will be the first ponds to receive any flooding that may occur during spring run off or periodic summer floods than ponds further away. In addition, the ponds closer to creeks may have a more consistent water regime and maintain enough water to last throughout the summer months. As a result whooping cranes select these areas due to the fact that they are more predictable from year to year. Kuyt (1993), observed new breeding pairs nesting further away from the creeks but there was a tendency for them to move their nests closer to the more stable and predictable water patterns closer to the creek in subsequent breeding seasons. Sufficient water levels for wading are critical for providing food for whooping cranes as well as protection against terrestrial predators. Whooping cranes are found in water depths approx. 30-35 cm for nesting (mean water depths for nesting in dry years, 14-16 cm and wet years 21-28 cm as measured 1 m from nest, Kuyt 1995). Among the three years the size of ponds the whooping cranes used increased as the summer progressed. This could be due to the increased mobility of the young and the fact that some of the shallow smaller ponds dry up or in an attempt to alleviate the impact of biting insects such as flies (Diptera). Besides water depth the creeks and streams also serve as source stocks for fish and invertebrates which allow for dispersal to occur in the ponds located close to the creeks. Whooping cranes exhibit considerable fidelity to their breeding territories and several pairs have nesting in the same general area for up to 19 consecutive years (Canadian Wildlife Service and U.S. Fish and Wildlife Service. 2005). This fidelity indicates that nesting whooping cranes may be able to predict areas that have relatively stable water levels from one year to the next. As indicated in the little variation which was detected in third order selection between years and individual pairs.

This is the first study to document in detail whooping cranes foraging strategy on their nesting grounds. Feeding on small items such as minnows and invertebrates requires whooping cranes to spend a lot of time foraging for themselves and for their young (as indicated by 46% of the observations were of feeding). Whooping cranes walk (wade) through the shallow ($\leq$ 35 cm) ponds in search of prey items focusing on areas in the ponds in open water near shorelines and along or in emergent vegetation.

Predictions of predator-prey interactions will often assume random search by predators and that their prey are encountered in proportion to their availability (Fryxell and Doucet 1993, Farnsworth and Illius 1998). However animals can use an area-restricted search to find prey by adjusting their movements in habitat types to find specific food items (Haskell 1997).

Area restricted response can be described as an intensive searching mode using a non random approach to locate preferred resources (Fortin 2000). Spatial memory can be used to find or avoid food patches in a heterogeneous landscape (Edwards et al. 1996, Dumont and Petit 1998, Laca 1998). Animals using area restricted response travel with high sinuosity and low speed. Extensive searching mode occurs when animals travel with low sinuosity and high speed because they are moving away from a patch of poor quality. In the ponds in WBNP, whooping cranes were observed most of the time to be moving with high sinuosity and low speed, as almost all (98%) of the observations were of whooping cranes standing, feeding or walking. Therefore, the cranes appeared to be using an area restricted response searching mode. Repeated use of territories and ponds indicated that the cranes have prior knowledge of the resources available in those particular locations. Thus the cranes kept returning to specific locations, and often feeding in the same ponds.

Ponds with fish had different environmental characteristics including significantly more emergent vegetation (*Scirpus validus*, *Typha latifolia*, *Carex* spp.), were significantly deeper (1 m, 5 m, and center), water temperature was colder, they were larger ponds, closer to creeks, with lower pH and dissolved oxygen (DO) and less exposed shoreline. Ponds that are located close to water courses (creeks and streams) receive flood waters in the spring which results in water fluctuation in the ponds that aid in emergent vegetation growth (with fluctuations in water levels), allows for higher water levels and the means for fish dispersal. Presence of fish may determine invertebrate composition due to predation and competition. The invertebrate taxa also differed in ponds where fish were not caught. Ponds where fish were caught had lower numbers of Anisoptera, Corixidae, Dytiscidae, Lymnae and marginally less Notonectidae. Aquatic invertebrate communities in this pond system are related to the presence/absence of fish (Sotiropoulos 2002). Ponds where fish were caught had lower numbers of Corixidae, Notonectidae, and Coleoptera (Sotiropoulos 2002).

While making their way on their initial trip into the nesting area Allen (1956) collected pike, three species of dace and longnose suckers from the Sass River but was surprised to also find fish in the shallow ponds and found four species: brook stickleback, finescale dace, northern pearl dace and fathead minnow. Wood frogs and chorus frogs were observed. Snails were very abundant and included Lymnaeidae. Allen (1956), noted that these snails and frogs must be important in the whooping cranes diet.

Fourth Order Habitat Selection

This study is the first to identify and describe in detail whooping crane fourth order habitat selection on their nesting grounds At the fourth order whooping cranes are omnivores as indicated by the varied items found in their fecal samples including emergent vegetation seeds, and animal parts. Specifically whooping cranes feed on fish, dragon fly nymphs and dragon fly adults, diving beetle larva and adults, water boatman adults, stonefly larva, backswimmer adults, snails and Diptera adults. Whooping crane scats were isotopically analyzed and found to have the same values as the fish indicating animal matter is present in the scats (Duxbury and Holroyd 1996).

At their nest ponds whooping cranes caught and consumed, Anisoptera nymphs, Anisoptera adults, fish, Gastropoda, Hemiptera, Coleoptera, Lestidae, a Ranidae and *Clethrionmys* spp. Anisoptera nymphs were the most common (41%) followed by fish (18%) and Gastropoda (18%). Due to the small sample size the results are to be taken cautiously (e.g. only one out of the four nest ponds where nest site observations occurred contained fish, based on sampling of the ponds post nesting). Until the eggs hatched at the nest whooping cranes did little feeding at the nest pond. This may be an attempt to conserve resources near the nest so there would be an abundance of prey available to feed the young post hatching or they might also fly off to feed in other ponds to reduce the potential of attracting predators to the nest pond, and by feeding in ponds other than their nest pond they let other cranes know their territory is occupied so other whooping cranes do not move in on their territory. In addition the adults may be gaining information on particular feeding ponds that would suit the needs of the family group once they leave their nest pond. Nest ponds may be selected for additional factors such as, nesting material, water depth and sight lines for predators rather than and abundance of prey for the adults. The strong association between nesting cranes and diatom ponds may be that cranes prefer long sight lines (open habitat), large amounts of open water, presence of bulrush, and deeper water (Timoney 1997)

The feeding trials that were done clearly indicate that whooping cranes including ones that have not foraged in the wild have the ability to easily capture the fourth order items found in wild whooping crane feeding ponds such as, fish, dragon fly nymphs, diving beetles adults, and snails.

In 1964, a young whooping crane was captured and excreted berries in the feces after the capture. Berries are likely supplementary food for the whooping crane, as the cranes are generally found feeding in the ponds and rarely on land. The food of the whooping crane appears to consist mainly of larval insects particularly when the chicks are small. When travel by family groups is possible frogs and berries are utilized on the margins of the pot-holes. It appears that the nesting pond is selected for other reasons than for food items as often the nesting pond does not have an abundance of food and the birds must travel a considerable distance in search of food (Novakowski 1966).

Scat analysis provides evidence of what cranes have eaten, yet only the indigestible parts of the food items will be passed through and therefore the analysis will not provide a complete picture of the crane’s whole diet (Setevenson and Griffith 1946, DeNiro and Epstein 1978). Cranes are assumed to be omnivores (Uhler and Locke 1969, Hunt and Slack 1985). Stevenson and Griffith (1946), and Allen (1952) were the first to quantify the food habitats of whooping cranes on their wintering grounds. They analyzed

35 crane scats and determined that blue crabs, clams, crayfish, fish, and snails were the most important food items. Allen (1954), analyzed the gizzard contents of an adult whooping crane shot on the refuge in 1948. Snails made up over half the material found. Orb snails (*Helisoma* sp.) were the most common however bladder snails (*Physa* sp.) were also found. Uhler and Locke (1969), reported on a second crane shot near the refuge in 1968 and again found that snails were the most abundant item in the gizzard (Uhler and Lock 1969). The gizzard contents of two young (< 1 year) whooping cranes were analyzed at Texas A & M, one in 1982 and one in 1984. Both had primarily acorn shells and small amounts of oyster shells and blue crab shells (Hunt and Slack 1985). According to Chavez-Ramirez (1996), plicate horn snails were common in whooping crane droppings in Aransas however during sampling there was a lack of live snails located although there were many empty shells leading to the speculation that cranes may be using the snail shells as grit. The primary food items identified in studies from Aransas Wildlife Refuge include blue crabs (*Callinectes sapidus*), razor clams (*Tagellus plebius*), wolfberry (*Lycium carolinianum*), fiddler crabs (*Uca* sp.), plicate horn shells (*Cerithidae pliculosa*), other snails (*Melampus coffeus*), (*Cyperus spp.*), *(Littorina* sp.), shrimp (*Panaeus* sp.), crayfish (*Cambarus hedgpethi*), and acorns (*Quercus virginiana*). Less common items in the whooping cranes diet in Aransas include fish, snakes and insects (Chavez-Ramirez 1996).

Energetics

A two year study was undertaken to describe the foraging ecology of the whooping cranes while on their wintering grounds in Aransas (Chavez-Ramirez 1996).

This study indicated that one or two items make up the majority of the cranes diet (blue crabs and wolfberry) throughout the winter. Energy consumption for specific food items was the sum of food items ingested per unit time multiplied by the mean weight of the food item determined from sampling. Energy intake rate for each food item was determined based on the number of food items consumed per unit time and the mean weight of the individual food items multiplied by the gross energy content of each food item. Gross energy content and metabolizable energy coefficients for blue crabs, wolfberry, and clams) were obtained from Nelson (1995) based on studies of captive whooping cranes (Chavez-Ramirez 1996). Active basal metabolic rate in daylight was estimated to be (65kj/hr) while all nocturnal behavior was assumed to be at reduced basal metabolic rate of (56 kj/hr). The daily energy balance of whooping cranes is based on the differences between total metabolized energy intake and daily energy expenditure. Blue crabs made up the majority (88%) of whooping cranes daily energy intake in 1992-93 and 46% in 1993-94. A single adult blue crab contains 424 kj (Chavez-Ramirez 1996). One whooping crane could meet most of its estimated daily energy requirements (88%) by consuming 5.26 crabs per day (Chavez-Ramirez 1996). A population of 235 cranes would require approx. 1,200 crabs per day (for 88% of their energy requirements). Chavez-Ramirez (1996) observed that wolfberry was utilized as the fruit ripened from Oct.-Dec. Nelson et al. (1996) reported that wolfberry provided the highest metabolic energy per kg of all food resources. He observed these higher energy amounts could have been off set by the scattered distribution of the resource, increasing search time and expending energy in foraging. Chavez-Ramirez (1996) observed that whooping cranes spent the majority of their time foraging in open water in the salt marshes. Chavez-Ramirez (1996) and Nelson et al. (1996) stated that limited winter food items resulted in whooping cranes not being able to accumulate and store adequate energy reserves for migration and breeding may be related to high mortality and low reproductive success. Spring migration was delayed in years with low food availability and therefore limited energy reserves (Bonds 2000).

Initial Activity

Initial activity of the adult cranes in WBNP consisted of feeding (probing) (46%) and standing (42%). The majority (91%) of the feeding observations were of the cranes feeding in water in the ponds. The whooping cranes were observed feeding in dry areas (probing) 9% of the time. Most (83%) of the feeding observations were of cranes in ponds estimated to be 35 cm or less in depth. These results indicate how important shallow wetlands are for whooping cranes.

Fifty-eight percent of the time the whooping cranes were observed feeding in or close ($\leq$ 5 m) to *Scirpus validus* and 21% and 26% of the time the whooping cranes were observed feeding in or close to *Typha latifolia* and *Carex* spp. respectively. A difference was detected in the number of observations of whooping cranes feeding in types of emergent vegetation between the three years. The main difference in emergent vegetation use may be attributed to water levels. In 1997, the water levels were the highest of the three years which may have resulted in the distribution of more water via spring flooding into areas containing *Carex* spp. causing them to be wet and the cranes used them more. In 1998, and 1999 with lower water levels flooding may not have covered as much *Carex* spp. in water.

Fifty-eight percent of the feeding observations were of whooping cranes in or close to ($\leq$ 5 m) *Scirpus validus*. Of the 188 ponds sampled, 70% contained *Scirpus validus*. Extrapolating from this, 83% of "available" ponds with *Scirpus validus* were used by whooping cranes for feeding. Whooping cranes were observed feeding in and close to ($\leq$ 5 m) *Typha latifolia* 21% of the time. Of the 188 ponds sampled, *Typha latifolia* was present in 24% of the ponds. Extrapolating from this, 88% of "available" ponds with *Typha latifolia* were used for feeding. Whooping cranes were observed feeding in and close to ($\leq$ 5 m) *Carex* spp. 21 % of the time. Of the total "available" ponds sampled, 38% contained *Carex* spp. Again extrapolating from this the whooping cranes used 55% of the available ponds with *Carex* spp. for feeding.

There were significant differences between which activities the whooping cranes were observed doing and whether they were in pond habitat or on a dry ridge/island. Feeding activity was most pronounced in ponds rather than on ridges or islands. When the whooping cranes were observed on the ridges surrounding the ponds or islands within the ponds 70% and 15% were of the cranes standing or walking respectively and only 6% feeding (probing).

Adult Whooping cranes exhibit plasticity in temporal patterns of activity. The yearly differences in frequency of activity may be due to interannual changes in environmental conditions, which in turn affect yearly prey abundance. Monthly differences are likely due in part to the requirements of raising their developing young.

On their wintering range whooping cranes were observed foraging 56% of the total time (Chavez-Ramirez 1996). Whooping cranes in the bays spent over 50% of the observed time foraging and a significant amount of time resting, comfort or other behavior. Whooping cranes in the salt marshes spent over 70% of the total time foraging and similar to the bays with little time spent on being alert. Whooping cranes in the uplands displayed quite different behavior with 58% of the time foraging.

Core areas vs Periphery Areas

No statistical difference was found when nesting pairs in the core area and the periphery area were compared over the three years of monitoring although there were more fledged young/nest in the core nesting pairs (0.82) vs the periphery nesting pairs (0.54). Water depths in the ponds were highest in 1997. In 1998 and 1999 water levels were only 81% and 78% respectively, of the 1997 level as measured in the center of sampled ponds. Fish caught per trap was highest in 1997 (17/trap) and lowest in 1999 (10/trap). Productivity of young per nest was highest in 1997.

Kuyt et al. (1992) suggested a one year lag in production of young and water levels. Annual precipitation from May 1st 1996 to April 30th 1997 was 40 cm (49 year average of 35 cm) and in 1997 there was record number of nests (to that date, 51 nests) (a minimum of 58 chicks were observed) 35 fledged young including two sets of twins survived the summer. Annual precipitation May 1st 1997 to April 30th 1998 was 41 cm and in 1998, 48 chicks were observed including 12 sets of twins and 26 fledged young (out of 49 nests) observed in August, no sets of twins survived the summer. Annual precipitation May 1st 1998 to April 30th 1999, was 25.4 cm was the lowest in 19 years. This coincided with low chick production in 1999, when 10 sets of twins and 18 fledged young (out of 48 nests and a minimum of 46 chicks hatched) were observed in August and no sets of twins survived the summer. June is the critical first month of a whooping crane chick's life and weather may play a role in the survival of the young during those first few weeks. June of 1999 received the most precipitation with 132 mm, whereas June ,1997, received 50 mm and in 1998 there was 28 mm of precipitation recorded in June, perhaps contributing to the lower survival rate of chicks in 1999.

Bonds (2000) study on the whooping cranes' wintering grounds found no differences in mean territory size among winter years in any location which suggested that their main prey item (blue crab distribution and abundance) did not strongly affect territory size. However decrease in crabs may have been compensated by increased use of other foods (Chavez-Ramirez1996) such as wolfberries, with territory size and location remaining the same. No differences were found in territory, land cover patch density, or density of salt marsh to open water edge at any location among winter years or among territories of pairs with and without chicks (Bonds 2000).

Pond Sampling

Sampling order may be an important consideration in choosing a technique for statistical analysis. It is expected that many counted species have higher numbers as the field season progresses. Pond depths, exposed shoreline and other pond attributes may vary according to when the field season data were collected. In total, 86% of the ponds were sampled in the months of July and August.

Environmental variables and characteristics of feeding ponds differ from randomly selected ponds. Whooping cranes were observed feeding in ponds that are deeper (at 1m, 5m from shore and center of pond), the water temperature is colder, ponds are darker in color, feeding ponds are larger in area, feeding ponds have a larger perimeter and less exposed shore line, more *Scirpus validus*, more *Typh*a *latifolia,* and more total emergents (only 4 out of the 94 feeding ponds did not contain any emergent vegetation whereas 20 random ponds did not contain emergents). Feeding ponds contained significantly more fish (79% of feeding ponds contained fish whereas 34% of randomly sampled ponds contained fish). Feeding ponds are significantly closer to creeks than random ponds. The difference between feeding and randomly selected ponds may be explained when the role of flooding is investigated. It is thought that water and fish are distributed into these ponds via flood water in the spring from the nearby creeks. Feeding ponds tend to be closer to the creeks are deeper and therefore may receive more flood water and with it fish. As a result of regular flooding and annual fluctuation in water levels emergent vegetation can establish itself. Feeding ponds have lower pH, lower DO than do randomly selected non observed feeding ponds. This may be related to the fact that feeding ponds are deeper and located closer to creeks and they might get a recharge of fresh water.

Water chemistry in the crane area is strongly influenced by dissolution of gypsum ($CaS0_{4*}2H_20$) rather than of carbonate rocks. The relatively high sulphate concentrations may act to limit species diversity (Timoney 1997). The predominant bedrock is gypsum karst bedrock responsible for the alkaline nature of the surface water (Timoney 1997).

Total phosphorus levels in the ponds result in their classification as mes-eutrophic to eutrophic (Wetzel 1983, Sotiropoulos 2002). Conductivity ranged from 630 µs/cm – 5620 µs/cm (Sotiropoulos 2002). Fishless ponds were significantly further away from a colonization sources than ponds where fish were caught (Sotiropoulos 2002). Invertebrates in the field were only categorized into broad (taxonomic groups, orders, suborders and families) Lymnaeidae, Corixidae, and Coleoptera were more abundant in fishless ponds than in ponds where fish were caught (Sotiropoulos 2002). Indicator species analysis identified Cladocera, and Graphoderus spp. as a significant indicator of ponds where fish were not caught (Sotiropoulos 2002). Temporal ponds indicated that Corixidae, Lethocercus spp., and Caenis spp. were found later in the summer whereas Coleoptera and Gerridae were found in the early parts of the summer. Invertebrate communities are strongly related to the presence or absence of fish, ponds with fish had lower numbers of invertebrate taxa including Corixidae, Notonectidae, and Coleoptera. This is probably due to predation (Bendell and McNicol 1987, Zimmer et al. 2000, Sotiropoulos 2002). The three main groups of invertebrates in ponds where no fish were caught were Coleoptera, Crustacea and Anisoptera (Sotiropoulos 2002). In ponds where fish were not caught two predatory guild emerges, one with beetles and one with odonates. Ponds with fish were consistently closer to creeks and rivers than ponds where fish were not caught (Sotiropoulos 2002). The biogeography of the ponds may determine the extent of fish (Willis and Magnason 2000).

Aquatic communities within feeding ponds, contained more *Culea inconstans*, more Dace spp. and more Planorbidae (Planorbidae), fewer Dytiscidae (Coleoptera) and fewer Lymnaeidae than randomly selected ponds based on numbers caught in minnow traps. No difference was detected between ponds types for the number of *Pimephales promelas*, Randidae, Notonectidae, Corixidae, Anisoptera, Trichoptera, Lestidae, *Lethocerus* spp..

Based on the biota captured with invertebrate (activity) traps there were significantly more *Culea inconstans* and Dace spp. in feeding ponds, but no difference between pond types detected with the other potential whooping crane prey species. No difference was detected between pond types for the number of tadpoles, Notonectidae, Corixidae, Anisoptera, Trichoptera, Lestidae, Coleoptera, *Lethocerus* spp., Lymnaeidae, and Planorbidae.

Emergent vegetation

Ponds with emergent vegetation are significantly deeper than those that do not contain emergent vegetation. Ponds that contain *Typh*a *latifolia* are deeper as measured at the center in than those that do not, *Scirpus validus*, and *Carex* spp. are marginally deeper (p = 0.100 level) at the center than ponds that do not contain those emergent types.

Fish

Ponds where fish were caught had significantly more emergent vegetation (only 4 ponds where fish were caught did not have emergents). Ponds with fish also had more *Scirpus validus*, *Typh*a *latifolia* and *Carex* spp. Ponds where fish were caught were deeper (at 1 m, 5 m from shore and center of pond), slightly higher salinity in fish ponds (p = 0.100), colder, closer to creeks and larger perimeter than ponds where fish were not caught. Ponds where fish were caught had less DO, lower pH, lower total phosphorus. No difference was detected between ponds were fish were caught and where they were not caught for levels of conductivity, Chlorophyll *a*, and size (area) of the ponds.

Fewer Corixidae, Anisoptera, Coleoptera, Lymnaeidae were caught in minnow traps in ponds that contained fish than in ponds where no fish were caught. Ponds containing fish had lower numbers of several invertebrate taxa likely as a result of predation or competition (Bendell and McNicol 1987, Zimmer et al. 2000, Sotiropoulos 2002). No difference was detected between ponds types with regard to tadpoles, Notonectidae, Trichoptera, Lestidae, Coleoptera, *Lethocerus* spp., and Planoribidae.

As with minnow traps results, there were less Corixidae caught in ponds that contained fish using invertebrate (activity) traps. No difference was detected between ponds types with regard to tadpoles, Notonectidae, Trichoptera, Lestidae, Anisoptera, Coleoptera, *Lethocerus* spp., Lymnaeidae, Planoribidae.

When results of the minnow traps and invertebrate activity traps are combined there were significant differences between ponds where fish were caught and where they were not caught. Fewer Corixidae, Anisoptera, Coleoptera, and Lymnaeidae and marginally fewer Notonectidae (at the p = 0.100) were captured in ponds where fish were caught. No difference was detected in the number of tadpoles, Trichoptera, Lestidae, *Lethocerus* spp., and Planoribidae.

Sotiropoulos, 2002 in a pond web study had similar findings, ponds containing fish had lower numbers of certain invertebrate taxa such as Corixidae, Notonectidae, and Coleoptera. This was attributed to the predation of fish on these various taxa. Sotiropoulos, (2002) also found that the zooplankton made up an important part of the fish diet.

Nesting habitat

Timoney (1997) found, at a scale of 300m^2 around their nests, whooping cranes were selecting a particular nest habitat rather than nesting at random on the landscape. According to Timoney (1997) potential indicators of whooping crane nesting habitat were: common bulrush (*Scirpus validus*), creeping spike-rush (*Eleocharis palustris*), and small bladderwort (U*tricularia minor*). Whooping cranes also appeared to prefer large concealment distances (ie. visually open habitat), with large amounts of open water, small amounts of terrestrial vegetation, and relatively short distances from the nest to open water (Timoney 1997). According to Timoney (1997), whooping cranes chose *Scirpus validus* habitat out to a radius of 200 m from the nest site.

The present nesting habitat of the whooping cranes, including the diatom ponds is probably unique (Timoney 1997). Historical records indicate that almost all of the Canadian nesting of whooping cranes was in aspen parkland, or the transition zone that lies between the plains and the parklands. These regions were likely occupied due to the greater precipitation in the parkland areas resulting in numerous potholes and sloughs (Allen 1952). Some of this habitat exists in Manitoba but more in Saskatchewan and Alberta (Allen 1952). While whooping crane nests were observed in the area of WBNP, historically there were more observations and nest sites in Saskatchewan, Manitoba and Alberta. Total observations in specific habitats were as follows: 47% in aspen parkland, 15% in transitional (plains to parkland), 13% in northern coniferous forest, 8% in shortgrass plains, 4% in river deltas, 2% in tundra and 3% in transitional (parkland to mixed forest) (Allen 1952).

The diatom ponds, gypsum karst-ground water discharge hydrology and permafrost (Timoney 1997) are very different from the prairie wetlands. Ground water discharge characterized by the dissolution of gypsum appears to be the chief process of this ecosystem and not fire (Timoney 1997). Timoney described at least four temporal scale dynamics occur in the nesting area:1) annual water cycle recharge-draw down of the ponds, 2) Surface water and ground water fluctuate on a 10-11 year hydrological cycle (McNaughton 1991), which linked to precipitation cycles (Kerr and Loewen 1995) and to broad global scale processes (Holdsworth et al. 1989). Fire at a 50-250 year cycle periodically sets back tree encroachment and succession, leading to thermokarsting and favoring pond formation, 4) Peat degradation operates on a scale of thousands of years (Timoney 1997).

Wintering Grounds

The third order habitat selection by whooping cranes in Aransas is primarily the salt marshes or salt flats (Stevenson and Griffith 1946, Allen 1952, Labuda and Butts 1978). The salt marsh is a heterogenous environment composed of distinct habitats at finer scales (Chavez-Ramirez 1996).

Bonds (2000) hypothesized that the whooping cranes wintering territories must have a minimum amount of open water salt marsh to support blue crab populations. If this minimum was not present cranes may compensate by distributing their foraging time among several areas. Four out of five non-contiguous territories identified were variable in location among winter years (Bonds 2000). She speculated that this behavior might have been the cause of territory shifts in location within a winter year rather than habitat composition. When crane families and sub-adult groups were attracted to large concentrations of food resources outside their normal territories such as in prescribed burns no territorial defense behavior was observed (Bishop 1984; Chavez Ramirez 1996).

Approximately 30 winter territories were identified over five winters with seven territories defined as variable (Bonds 2000). Territories were considered variable when whooping cranes changed their territory location from one winter to the next. No significant relationships were detected between contiguous and non-contiguous territories and characteristics of presence or absence of chicks, territory location, winter year, male age, female age or the time the two birds had been paired. Bonds (2000) results were highly variable, and the most important conclusions were from observations of similarity among locations. All locations were dominated by salt marsh and salt marsh open water land-cover (Bonds 2000).

Migration Habitat

Whooping crane young separate from their parents near the end of their northern migration (Howe 1989, Lewis 1995). During migration in the fall whooping cranes usually take two days from WBNP to get to a staging area in Saskatchewan. The birds remain for one to five weeks in the grain fields and wetlands of Saskatchewan. The remaining migration across the prairie states toward the Texas Gulf usually takes one week (Howe 1989). Radio-tracking data demonstrated that individual whooping cranes do not use the same stopover locations from year to year (Howe 1989).

Migration routes of whooping cranes are learned rather than innate which suggests that movement may be partly directed by recognition of landscape features such as streams and wetland mosaics (Gill 1990). During migration whooping cranes primarily roosted in shallow palustrine wetlands and submerged sandbars in rivers (Richert 1998). Possibly whooping crane habitat selection is geared more toward landcover structure than a specific habitat type. Many researchers have indicated that roost habitat consistently has included open shallow water at least 100 m from tall vegetation and human related disturbance (Lingle et al. 1984, Ward and Anderson 1987, Armbruster 1990). Lingle et al. (1987) suggested that habitat selection during migration was related to family structure. Richert (1998) found that 2,160 m was the extent that most (> 75%) cranes fly from roost to foraging sites. On migration it was found that whooping cranes selected wetlands at each scale when habitat selection occurred (Richert 1998).

On the wintering grounds whooping cranes are at risk from accidental petroleum and chemical spills, habitat loss from erosion, disease outbreaks and late season hurricanes (United States Fish and Wildlife Service 1994). Petroleum products are transported by the Gulf Intra Coastal Waterway which bisects whooping crane habitat.

Conclusions

Whooping cranes fed primarily in ponds that were close to creeks, less than 35 cm in depth, contained emergent vegetation, contained fish and were less than 150 m in diameter. Their diet was varied and consisted of dragon fly nymphs, fish, snails, diving beetles, water-milfoil and pond weed. Whooping cranes are opportunistic feeders and will eat frogs, and voles given the chance.

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Chapter 5

HOME RANGES AND MOVEMENTS OF WHOOPING CRANES

Introduction

Wetlands in and around Wood Buffalo National Park (WBNP) represent the only continually inhabited breeding grounds of the endangered whooping crane (*Grus americana*) in the world. Whooping crane nesting sites were first observed in WBNP in 1954 (Fuller 1955) when five pairs were located. The current (2007) population numbers close to 235 individuals.

A three-year study (1997-1999*)* was initiated by Parks Canada and the Canadian Wildlife Service (CWS) in WBNP to identify the main components in the whooping cranes summer nesting range including determining the size of their home ranges.

Study Area

The study area was in WBNP in latitude range 59^0 45' to 60^0 30' N and longitude 112^0 45' to 114^0 00' W. For a detailed description of study area refer to study area in Chapter 2.

Objectives

1) Determine the home ranges of selected pairs (second order habitat selection as defined by Johnson 1980) of nesting whooping cranes; and

2) Determine the daily movements of selected pairs of nesting whooping cranes.

Research Question

What is the second order habitat selection of whooping cranes on their nesting grounds?

Methods

Home Ranges

A total of 868 locations (not including nest observations) of selected nesting pairs of whooping cranes were recorded from 148 aerial surveys over the three years between April and September (Table 5-1).

Table 5-1: Number of aerial surveys conducted during the summer months, 1997-1999.

Month	**1997**	**1998**	**1999**	**Total**
April	0	0	3	3
May	4	6	9	19
June	35	10	21	66
July	8	11	11	30
August	3	12	12	27
September	0	3	0	3
Total	50	42	56	148

At the time of the initial observation the location of each whooping crane was plotted onto a mylar attached to an air photo (false-colour infra-red, scale 1:15,840). The airphoto locations were then transformed onto 1-m resolution digital georeferenced airphotos in PCI EASI/PACE Software v6.2. This software generated co-ordinates in degrees, minutes and seconds for each position collected during the aerial surveys. Determining home range boundaries was produced with the HRE (Home Range Extension) for Arc View 3.x and Animal Movement SA v2.04 beta . Two methods were selected for home range analysis (second order habitat selection), the fixed kernel method and the minimum convex polygon method (MCP). The fixed kernel method calculates a frequency of use within the territory as well as activity centers of multi-modal, non-normal locations (Silverman 1986, Worton 1989). The fixed kernel creates an estimate of density that is calculated at each grid intersection from the average of all densities of all the kernels that overlap on that particular point. A Contour line is placed around the percentage of location points where the whooping cranes were observed. The MCP, is a non-statistical method for delineating territories (Samuel and Fuller 1994). The MCP method does not consider the distribution of use within the home range. The MCPs are constructed by connecting the peripheral points of a group of points such that the angles are greater than 180^0. Unlike the kernel methods, MCPs do not indicate how intensively different parts of an animals range are used.

Daily Movements

The movements were determined using the location of the adult that was closest to one or both young. Locations were recorded daily for up to 10 consecutive days per summer month. Pairs were identified by their composite nesting areas (CNA), presence of specific colour coded leg bands, and/or presence/absence of young. Composite nesting areas were defined by Kuyt (1993) as the nesting territory of a pair of cranes over several years including nesting, roosting and feeding areas (Table 5-2).

Table 5-2: Nesting pairs monitored

Pair	Corresponding Annual Nest Numbers	Banded	CNA
A	(3-97, 3-98, 5-99)	Y	A-5
B	(44-97, 6-99)	N	A-
C	(4-98)	N	A-
D	(15-97, 5-98, 7-99)	Y	A-2
E	(5-97, 47-99)	Y	A-6
F	(6-97, 8-98, 1-99)	Y	SK-4
G	(40-98)	Y	K-21
H	(42-98, 8-99)	N	K-7

I	(18-98, 13-99)	Y	K-19
J	(20-97, 15-98, 15-99)	Y	K-11
K	(14-98, 16-99)	N	NY-5
L	(23-97, 20-98, 37-99)	Y	K-20
M	(39-97, 23-98, 11-99)	Y	S-22

Results:

Home Ranges

The areas used by the whooping cranes were delineated as two areas of utilization distribution (UD), the central area of their range where 50% of the locations occurred and the UD where 95% of the locations occurred (Table 5-3). The second analysis of home range used MCPs with 100% of the locations delineated (Table 5-4) (Figures 5-1 to 5-14).

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Table 5-3: Home ranges of nesting whooping cranes in WBNP using the fixed kernel method (50% UD and 95% UD), >30 locations.

Nest Pair	Home Range (km^2)		n (total observations)	Years Monitored
	50%UD	95%UD		
A(99)	0.81	3.25	38	1
B	0.53	3.14	74	2
C	0.26	1.04	18	1
D	0.17	2.80	88	3
E	0.34	2.74	52	2
F	0.13	1.36	113	3
H	0.56	6.27	32	2
I	0.46	4.79	64	2
J	0.36	3.36	82	3
K	0.17	1.79	32	2
L	0.53	4.96	116	3
M	0.39	3.48	98	3

The mean home range for nesting pairs using the fixed kernel method (50% and 95% utilization distribution) of pairs with >30 locations was 0.39 km^2 (SE = 0.1), 3.25 km^2 (SE = 0.4) respectively.

Table 5-4: Using the Minimum Convex Polygon method (100%).

Nest Pair	Home Range (km^2)	n (total observations)	Years Monitored
A* (97)	10.21	28	1
A (98)	0.79	13	1
A (99)	1.92	38	1
B	3.24	74	2
C	0.57	18	1
D	3.65	88	3
E	2.16	52	2
F	4.90	113	3
G	1.79	20	1
H	4.82	32	2
I	4.73	64	2
J	2.91	82	3
K	1.38	32	2
L	5.63	116	3
M	3.94	98	3

The mean home range for nesting pairs using the minimum convex polygon method (100%) was 3.51 km^2 (SE = 0.63), if the large range of nest pair *A-97 was not included the mean home range would be 3.03 km^2 (SE = 0.44). Nest pair A-97 had the largest variation in home range between years (Table 5-5).

Table 5-5: Comparison by year using the Minimum Convex Polygon method (100%).

Nest Pair	Year	Home Range (km^2)	n (total observations)
A*	(97)	10.21	28
A	(98)	0.79	13
A	(99)	1.92	38
B	(97)	1.89	34
B	(99)	2.43	40
C	(98)	0.57	18
D	(97)	1.0	34
D	(98)	0.32	11
D	(99)	2.79	43
E	(97)	1.56	31
E	(99)	1.08	21
F	(97)	0.8	35
F	(98)	2.18	32
F	(99)	1.49	46
G	(98)	1.79	20
H	(98)	2.65	9
H	(99)	3.71	23
I	(98)	2.28	22
I	(99)	2.71	42
J	(97)	0.85	33
J	(98)	2.68	26
J	(99)	1.93	23
K	(98)	1.37	32
L	(97)	2.35	34
L	(98)	5.02	39
L	(99)	2.80	43
M	(97)	1.35	36
M	(98)	2.42	33
M	(99)	2.27	29

The mean home range for 1997 using MCP 100% was 1.4 km^2 (SE = 0.2), in 1998 was 2.1 km^2 (SE = 0.4), and in 1999 was 2.3 km^2 (SE = 0.2). Between the three years no statistical significance was detected in size of home ranges although when 1997 (excluding nest pair A-97) and 1999 are compared using t-test, a significant difference was detected (P = 0.017) with 1997 home ranges being significantly smaller than 1999.

The smallest home ranges over the summer months occurred in June (Table 5-6 to 5-8).

Table 5-6: Minimum Convex Polygon method (100%) for June. Minimum of 10 locations.

Nest Pair	Home Range (km^2)	n (total observations)
*A (97)	4.68	23
A (99)	0.87	15
B	1.40	42
D	1.0	40
E	0.52	22
F	0.50	51
I	1.85	26
J	0.84	36
L	2.21	45
M	2.13	39

The mean home range of nesting pairs in June was 1.6 km^2 (SE = 0.4) without the large home range of pair *A-1997 the mean home range would be 1.26 (SE = 0.22).

Table 5-7: Minimum Convex Polygon method (100%) for July. Minimum of 10 locations.

Nest Pair	Home Range (km^2)	n (total observations)
A (99)	1.08	11
B	1.62	19
D	2.80	28
E	1.30	17
F	1.14	28
I	2.17	20
J	2.07	27
K	0.36	11
L	1.87	36
M	2.24	30

The mean home range of nesting pairs in July was 1.67 km^2 (SE = 0.3).

Table 5-8: Minimum Convex Polygon method (100%) for August. Minimum of 10 locations.

Nest Pair	Home Range (km^2)	n (total observations)
A (99)	0.35	10
B	1.04	10
E	0.95	10
F	3.16	22
H	2.51	13
I	2.86	18
J	1.62	16
L	3.18	27
M	1.66	15

The mean home range of nesting pairs in August was 1.95 km^2 (SE = 0.3). No statistical difference was detected between months and size of home range.

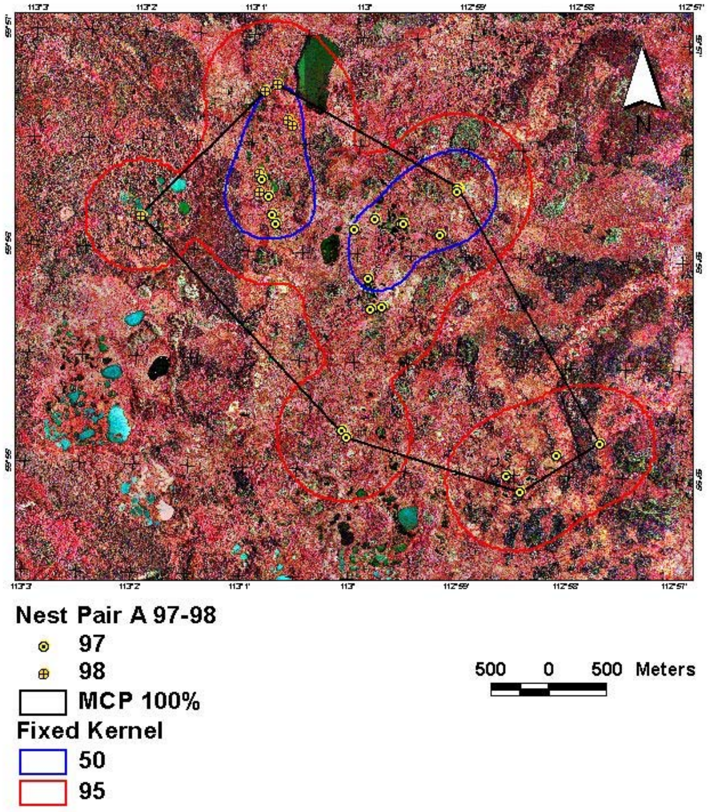

Figure 1: Nest Pair A, home range, 50% and 95% utilization distribution and MCP 100%.

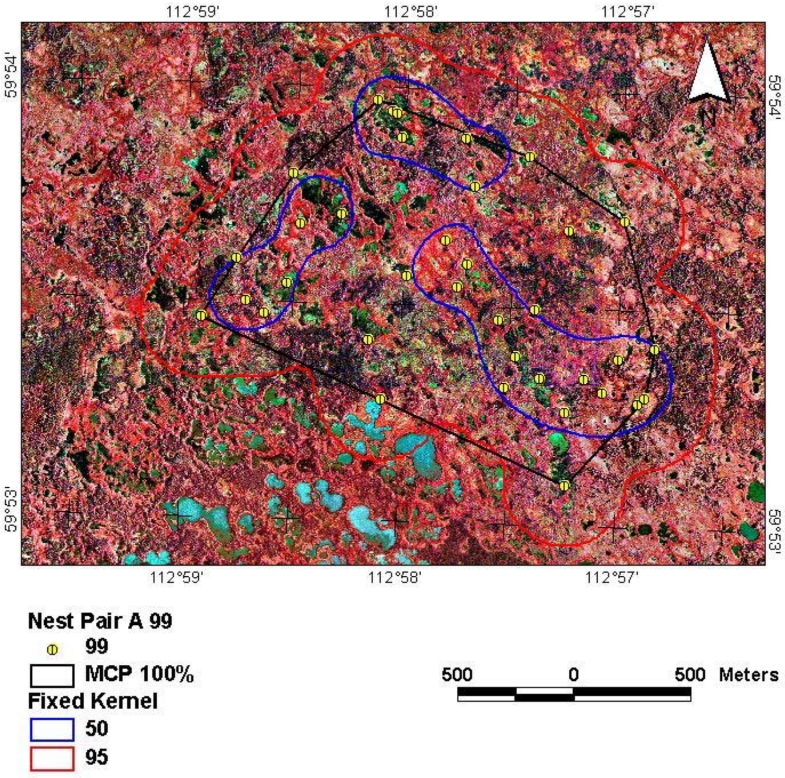

Figure 2: Nest Pair A99, home range, 50 and 95% utilization distribution and MCP 100%.

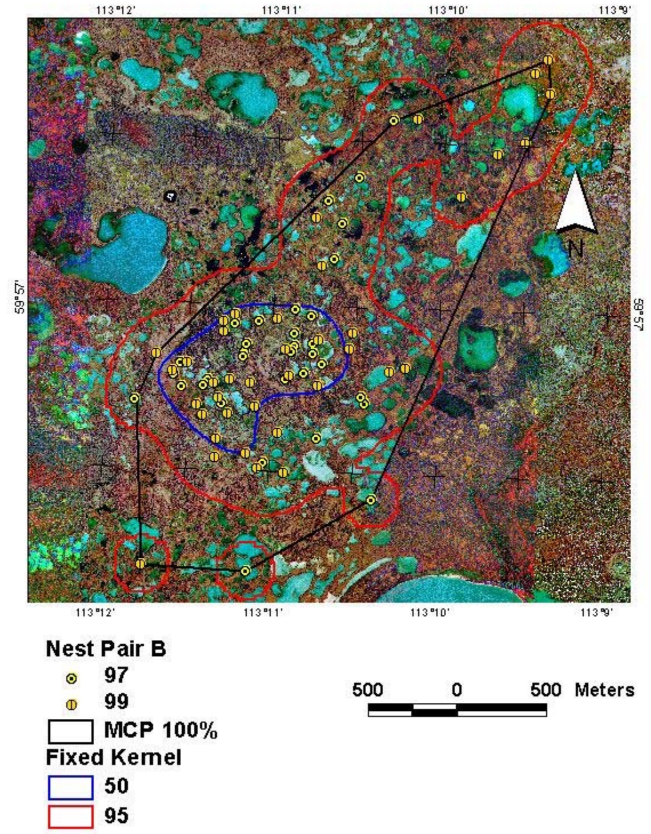

Figure 3: Nest Pair B, home range, 50% and 95% utilization distribution and MCP 100%.

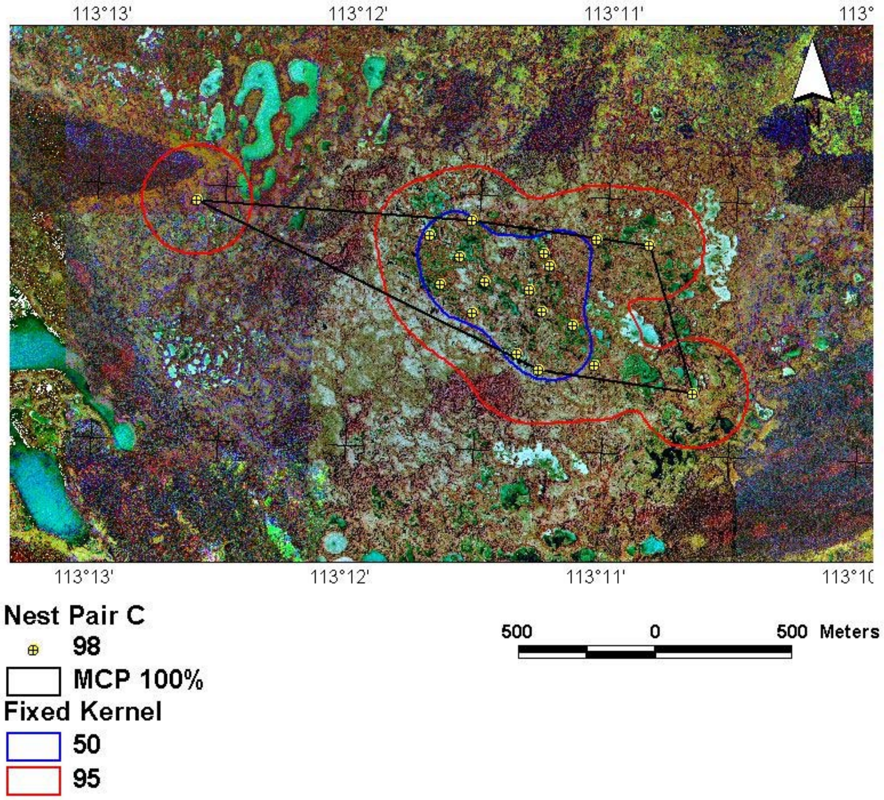

Figure 4: Nest Pair C, home range, 50% and 95% utilization distribution and MCP 100%.

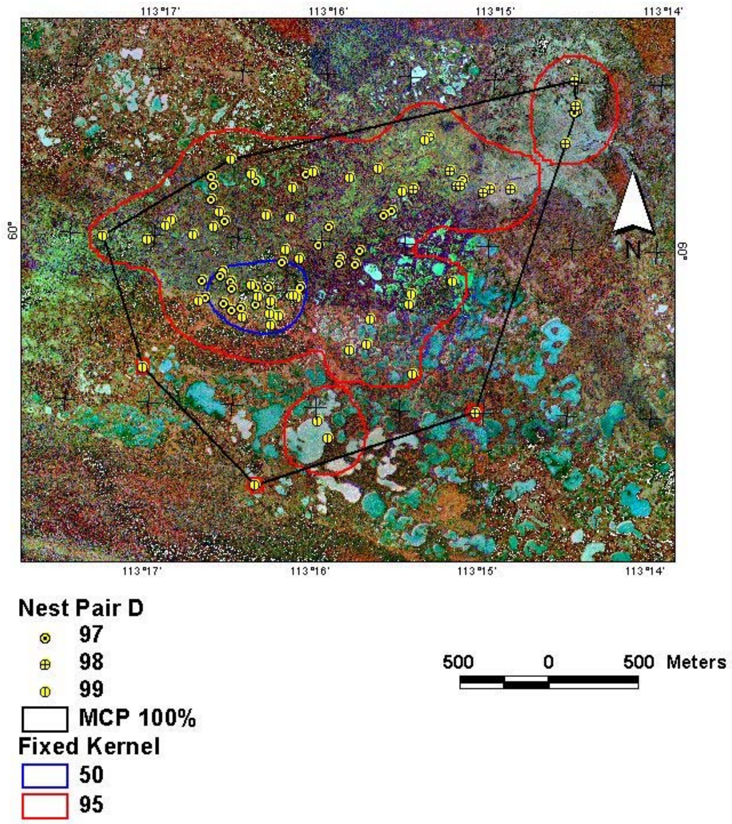

Figure 5: Nest Pair D, home range, 50% and 95% utilization distribution and MCP 100%.

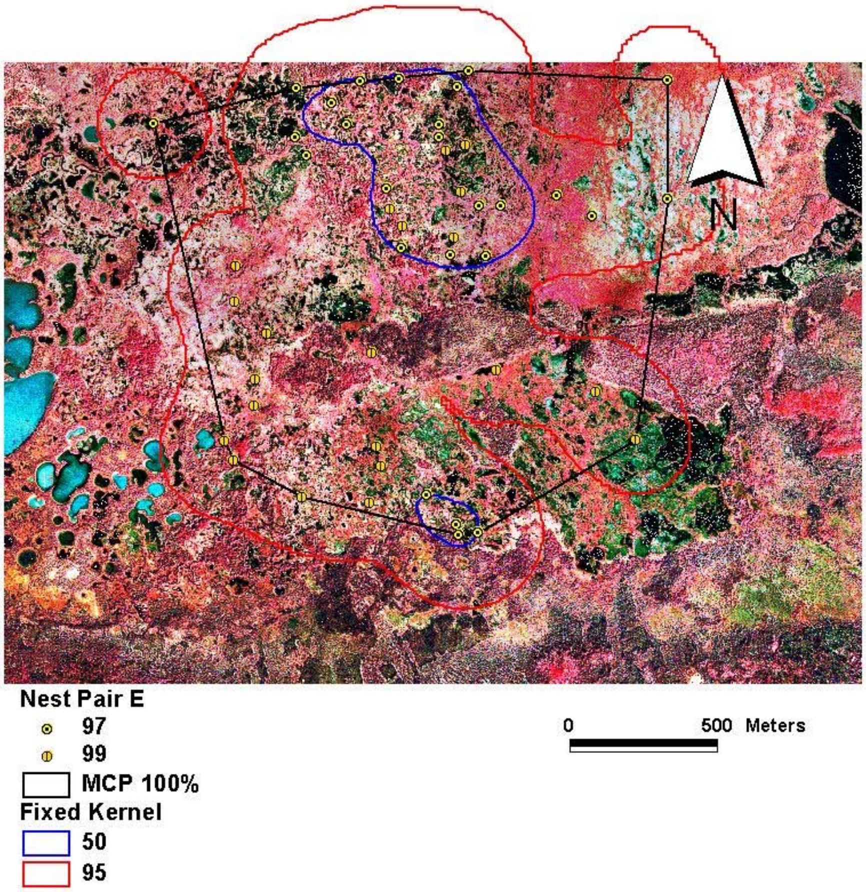

Figure 6: Nest Pair E, home range, 50% and 95% utilization distribution and MCP 100%.

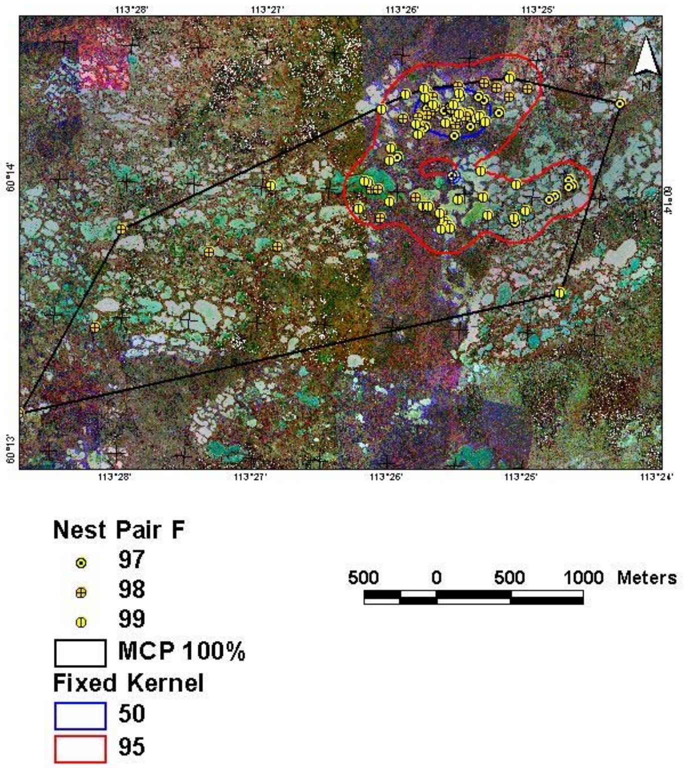

Figure 7: Nest Pair F, home range, 50% and 95% utilization distribution and MCP 100%.

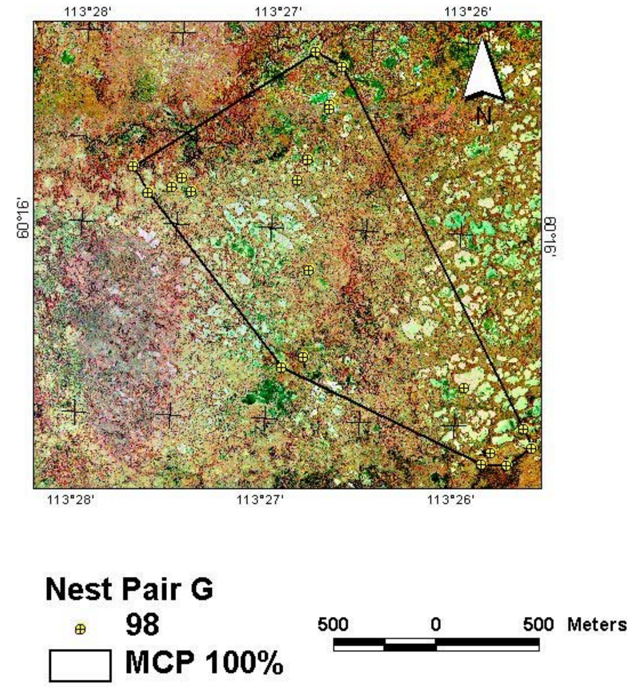

Figure 8: Nest Pair G home range, 50% and 95% utilization distribution and MCP 100%.

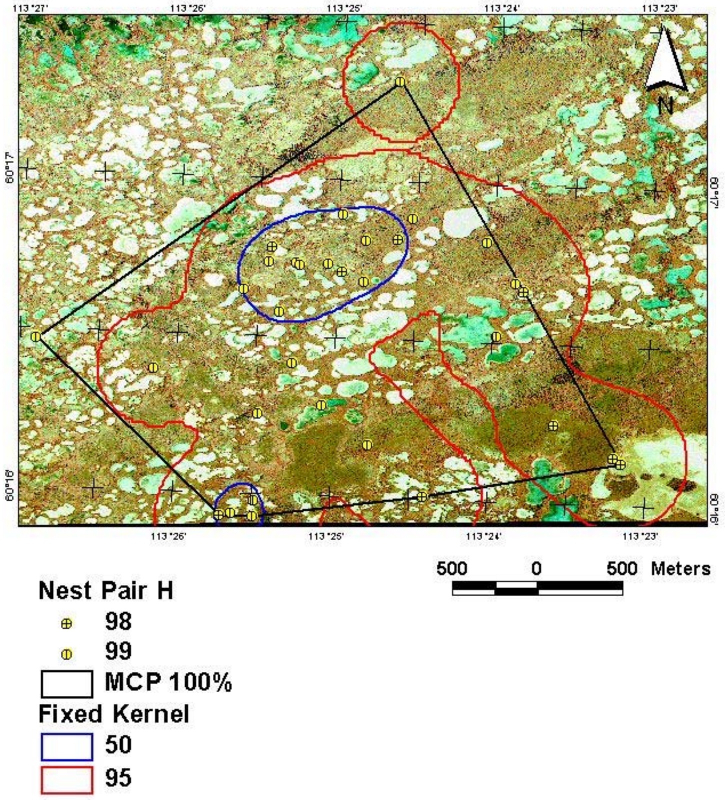

Figure 9: Nest Pair H home range, 50% and 95% utilization distribution and MCP 100%.

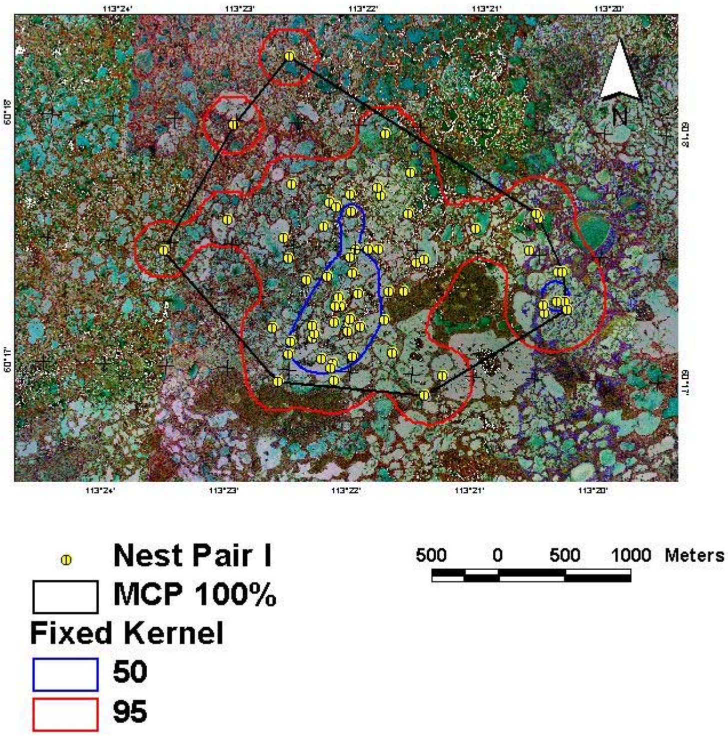

Figure 10: Nest Pair I home range, 50% and 95% utilization distribution and MCP 100%.

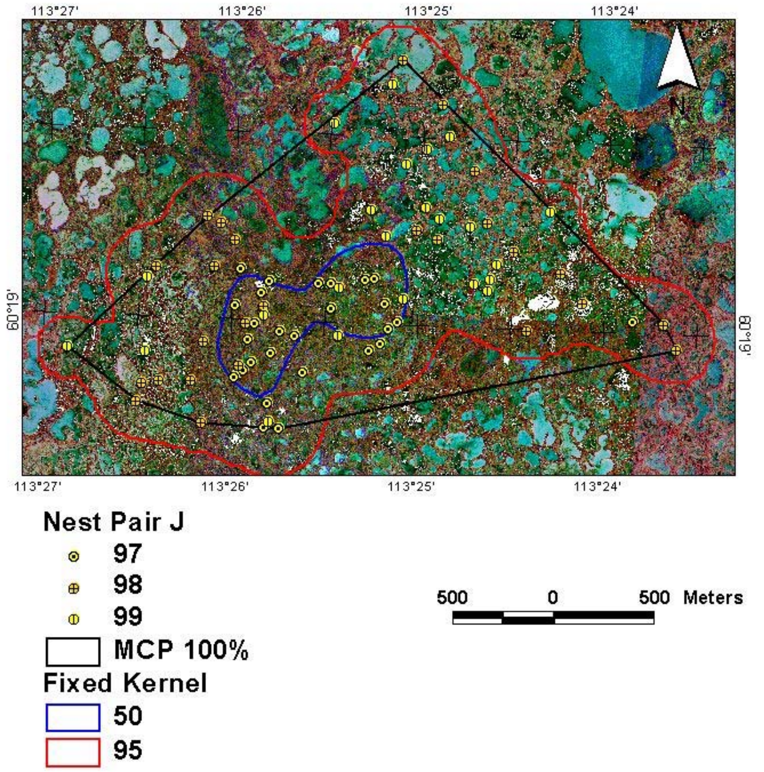

Figure 11: Nest Pair J home range, 50% and 95% utilization distribution and MCP 100%.

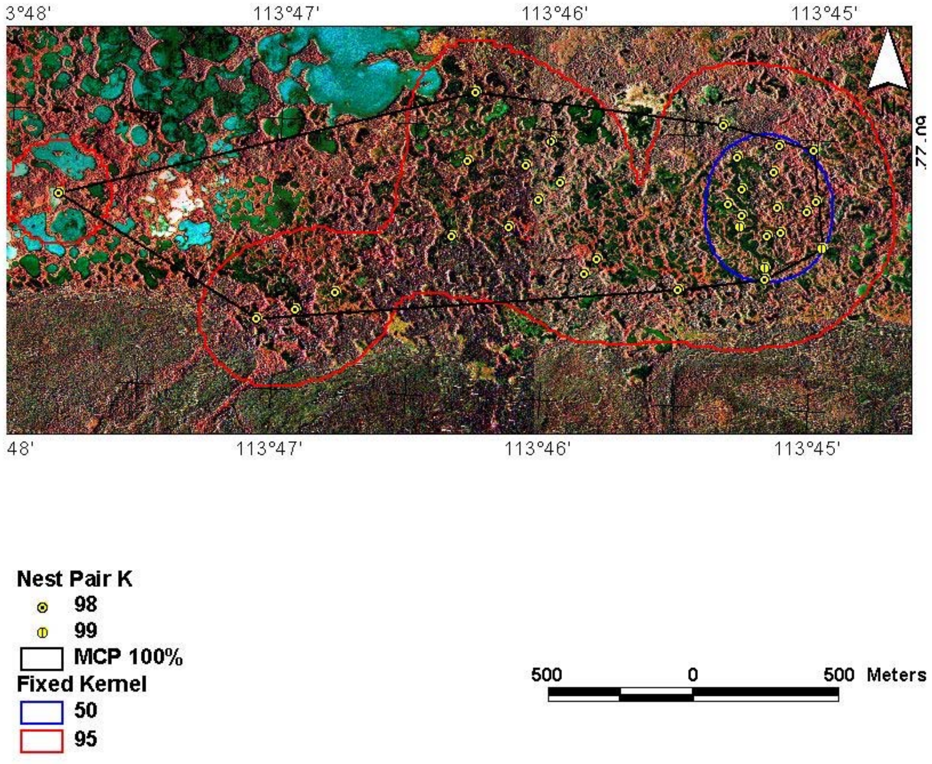

Figure 12: Nest Pair K home range, 50% and 95% utilization distribution and MCP 100%.

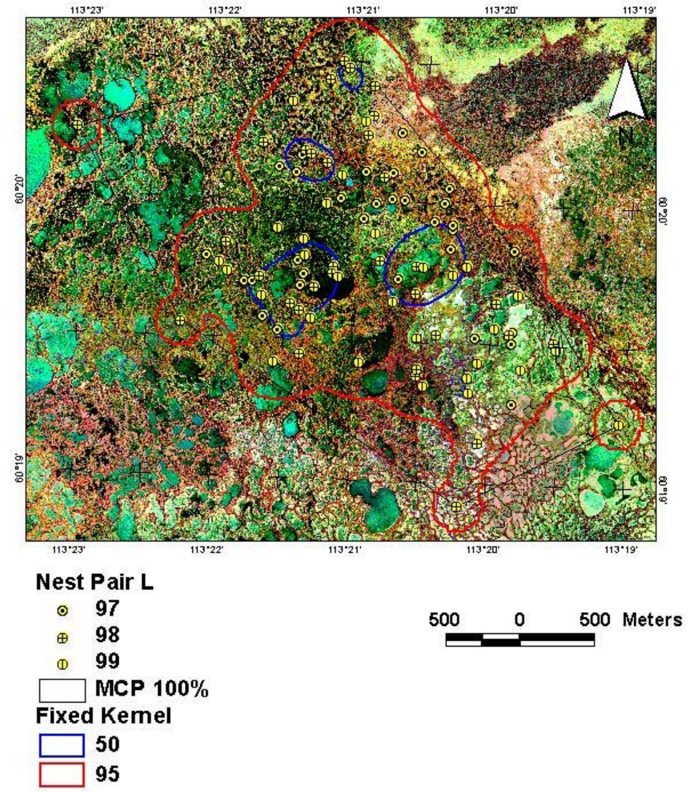

Figure 13: Nest Pair L home range, 50% and 95% utilization distribution and MCP 100%.

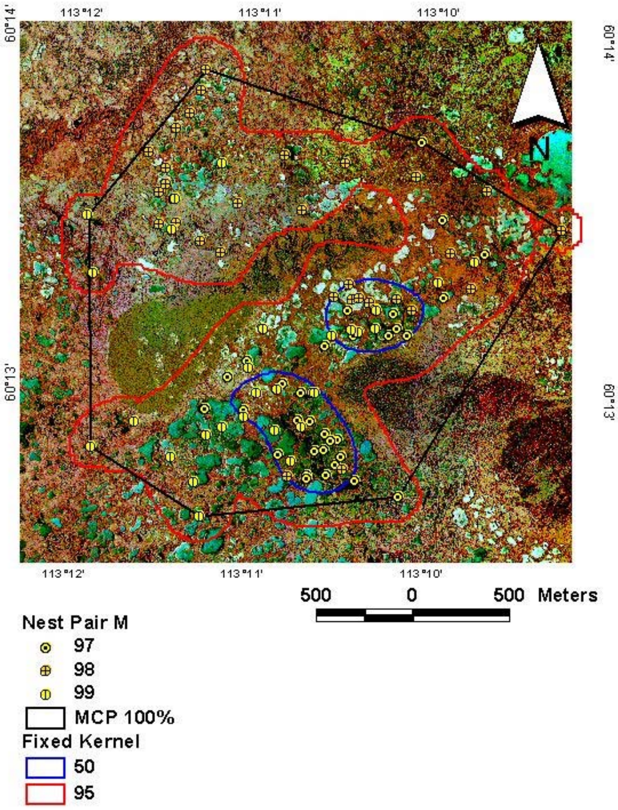

Figure 14: Nest Pair M home range, 50% and 95% utilization distribution and MCP 100%.

Daily Movements

Daily movements of he whooping crane family groups increased as the summer progressed (Table 5-9).

Table 5-9: Daily (24 hr) movements (m) during the summer months for all nesting pairs observed, 1997-1999.

Month	Mean	SE	n
June	386.0	31.0	259
July	696.0	59.0	177
August	892.0	91.0	116

Using a Kruskal-Wallis one way ANOVA on ranks (normality test failed), there is a statistically significant difference ($P = <0.001$), ($H = 28.79$ with 2 df) in movements between months, with larger movements occurring as the summer progresses.

Daily (24 hr) movements (m) during the summer months for nesting pairs with young for June, July and August, 1997-1999 was 595.0 m ($n = 552$, $SE = 20.0$) and pairs without young 700.0 m ($n = 57$, $SE = 70.0$). Movements of whooping crane pairs without young was significantly larger than pairs with young (Mann Whitney U-test), ($P = 0.048$) over the summer months.

In June, the average daily distance of a whooping crane family from their nest pond (excludes cranes on nests) was 818.0 m ($SE = 33.0$), in July the average distance was 1055.0 m ($SE = 38.0$) and in was August 1117.0 m ($SE = 49.0$). There was a statistical significance difference ($P = < 0.001$), (one way ANOVA on ranks, Kruskal Wallis test statistic), ($H = 55.89$ with 2 df,) detected between the distance from a pair's nest pond and where they were observed as the summer progressed the pairs moved further from their nest pond (June-August).

Discussion:

Second Order Habitat Selection

Second order habitat selection includes the animal's home range (Johnson 1980). Territory is often defined as the defended portion of an animal's range (Samuel and Fuller 1994). Unusual movements beyond the normal area are viewed as excursions and are not considered part of the territory (Samuel and Fuller 1994). Walther et al. (1983) suggested that the territory should include that part of the range that is actively defended and has an established boundary. The interaction between habitat composition and predator avoidance can also determine home range size and habitat use (Bishop 1988). Breeding crane's territories often include a nesting, foraging, and roosting areas and will actively defend these areas from other cranes (Bishop 1988). Gill (1990) stated that territory size was not necessarily controlled by food and energy requirements but also by density of competitors for available space.

Home Range

The whooping crane is the only crane species that have territories that remain as separate units nocturnally as well as diurnally (Bishop 1984). Territorial defense behaviors include unison or guard calling, head shaking, chasing off intruders, and preening. Labuda and Butts (1979) suggested that habitat use patterns were caused by food supply, but perhaps territory selection was related to family history. Stehn and Johnson (1987) found that there was a tendency for new pairs to establish their territory near the area where the male wintered as a chick, 75% of paired males established territories in the same areas as their juvenile winter territory.

The mean home range based on the MCP method in this study was 3.51 km^2 (SE = 0.6) ranging in size from 0.57 km^2 to 10.21 km^2. Although if the large home range of nest A-97 was not included then the mean home range would be 3.03 km^2 (SE = 0.4). The 95% utilization distribution was 3.25 km^2 and a 50% utilization distribution of 0.39 km^2.

Kuyt (1993) estimated home ranges for isolated breeding pairs in WBNP to range from 2.0 - 18.9 km^2. In areas of higher density the range was 3.2 to 4.2 km km^2 and average home ranges of 13 pairs in the core nesting areas (Sass, Klewi, Sass-Klewi) was 4.1 km^2. Compared with Kuyt's (1993) study the mean home ranges are similar in size even though the population increased from 33 nesting pairs in 1991 to 48 nesting pairs in 1999 an increase of 31%. The variation in the size of the home ranges between nesting pairs may be related to abundance and distribution of food resources.

In Aransas, Jean Bonds (2000) used remote sensing and the MCP method to determine winter territory size of whooping cranes. The mean territory size in Aransas is 163 ha (1.63 km^2). Previous studies on territory size in Aransas by Allen (1952) and Blankinship (1976) found mean territory size to be 176 ha (1.76 km^2) (n = 10) and Stehn and Johnson (1987) reported mean territory size without overlapping and shared areas was 117 ha (1.17 km^2) (n = 14). The summer territories are approx. twice as large as the winter territory for whooping cranes. This may be due to the presence of defending larger areas to protect the young chicks, and that the nesting area has lower quality forage than Aransas.

Jean Bonds (2000) found that there was high variability in the size of whooping cranes winter territories. Chick presence or absence showed no effect on mean territory size among any locations on the wintering grounds. For the five year period of Jean bonds (2000) study, the Aransas Wildlife refuge contained a total of 15-16 territories an increase of only 1-2 territories from Stehn and Johnson's 1987 study. Jean Bonds (2000) research findings did not support the trend proposed by Stehn and Johnson (1987) that territory size decreased as territory crowding increased. Similar to the results of this study even though an increase of 31% nesting pairs the size of their home ranges did not significantly change.

Jean Bonds (2000) study found no differences in mean territory size among winter years in any specific location which suggested that food (blue crab) abundance did not strongly affect territory size. The smallest mean territory size was on the Aransas National Wildlife Reserve was 0.63 km^2 and the largest territory was at San Jose Island 2.99 km^2 whereas in WBNP on the nesting grounds the size of home ranges varied from 0.57 km^2 to 5.63 km^2 (not including nets pair A-97).

As the whooping crane population has increased so has the area of occupied winter habitat in Aransas. Although the increase in winter range has not been in proportion to population increases (Chavez-Ramirez 1996). New pairs tend to establish territories near their parents resulting in a decline in average territory size (Stehn and Johnson 1987). As more cranes occupy winter habitat and the territories are reduced in size, the possibility exists for a situation where there is over use of food resources.

A study (Bishop 1988) on Florida Sandhill Cranes (*Grus canadensis pratensis*) found the average home range to be 9.76 km^2 (95% harmonic mean) or 6.57 km^2 (Minimum convex polygon method). The average home range (convex polygon) of Florida sandhill cranes in Florida was about 13.70 km^2 for territorial adults and 5.5 km^2 for resident adult crane pairs (Nesbitt 1990).

Daily Movements

As would be expected as the chicks grow and become increasingly more mobile, the daily movements of the family groups also increases. In June the family groups averaged 386.0 m per day (SE = 31.0) and in August they averaged 892.0 m (SE = 91.0). Average daily distances from the whooping cranes nest pond also increased as the summer progressed and ranged from a low of 818.0 m in June to 1117.0 m in August.

Conclusions

In order to achieve the required number of breeding pairs as outlined in the whooping crane recovery plan (Canadian Wildlife Service 2005) will require a minimum of 3.5 km^2 of relatively continuous quality habitat fro each nesting pair.

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Chapter 6

Conclusion and Recommendations

Chick Mortality

Why do whooping cranes lay two eggs but normally raise one young? Why invest the extra energy into laying and incubating two eggs if there is little fitness incentive to raise a second chick. It would seem the costs of laying and incubating an extra egg each year is a gamble whooping crane's are willing to take with the occasional payoff year when both young survive and are recruited into the population. During the occasional above average habitat year with above average food and water supply they are capable of raising two young. How do whooping cranes determine if the upcoming summer is going to be above average? Whooping cranes use a strategy of resource tracking. Upon arrival on their nesting grounds many ponds are still ice covered and predicting what the upcoming summer's resources are going to be is difficult so they lay two eggs in case the summer turns out to be above average. If the summer turns out to be average or below average then whooping cranes can reduce their brood size from two to one. By hatching their eggs 2-3 days apart whooping cranes provide the first hatched a competitive advantage over the second younger hatched. Over the next few days and weeks the adults have additional information on what resources may be like for the remainder of the summer and decide whether it is an above average year or not and how much resources will be diverted to the second "bonus" chick. The advantage bestowed on the older chick provides it with the tools (larger and stronger) to physically dominate its younger sibling allowing it to gain more food resources through intercepting the adults off the nest, and the ability to out compete it's sibling directly through physical contact and bullying it into submission.

It appears the second egg has at least two roles, first it serves as a backup or replacement if there are problems with the hatching of the first egg. Once the first egg hatches and the first chick appears to be functioning normal the adult whooping cranes will sometimes lose interest in the second egg neglecting to turn the egg, and may even abandon the egg on the nest. When the second egg does hatch the adults will feed the first chick that they come into contact with which is often the older more mobile chick. The adults do not interfere with the aggressive physical contact between the chicks which is primarily one sided with the older chick bullying the younger smaller one. The family group departs the nest pond within two days of the second egg hatching, and the smaller second hatched young is forced to keep up with the family group before it has built up enough strength and it ends up being worn down and eventually lags behind the family group and gets preyed upon or abandoned by the adults.

If however, something should happen to the older chick in the first few critical days (like a predator taking the older chick) then the adults have the second chick to raise and replace the first chick. In addition, if the conditions are deemed to be above average by the adults then both young are raised for a longer period of time. Out of 22 sets of twins monitored, 16 young were fledged, of these at least two (13%) were the younger siblings. One older sibling was preyed upon and the adults had the second offspring as a replacement and fledged this marginal offspring. One nesting pair in 1997 raised both their young throughout the entire summer. While the outlook for many second marginal eggs and chicks is not great there are enough that survive so the adults continue to lay two eggs.

Habitat Selection and Use

Second Order Habitat Selection

Whooping crane's home range based on the minimum convex polygon method was 3.51 km^2 (SE = 0.6) ranging in size from 0.57 km^2 to 10.21 km^2. Using the fixed kernel method the 95% utilization distribution was 3.25 km^2 and a 50% utilization distribution of 0.39 km^2.

Third Order Habitat Selection

Whooping cranes do not feed randomly across their nesting pond complex but are found in ponds that are deeper, colder, closer to creeks, larger, and contain more emergent vegetation than randomly selected ponds. All of these variables are linked to the flooding component associated with distance to creeks. Ponds that are closer to creeks or streams are the first ponds to receive any flooding that may occur during spring run off or periodic summer floods than ponds further away. In addition, the ponds closer to creeks may have a more consistent water regime and maintain enough water to last throughout the summer months. As a result, whooping cranes select these areas due to the fact that water levels in these ponds are more predictable from year to year.

Fourth Order Habitat Selection

The diet of adult whooping cranes was varied and consisted of dragon fly nymphs, fish, snails, diving beetles, water-milfoil and pond weed. The cranes are opportunistic feeders and ate frogs, and voles given the chance. The diet of young whooping crane chicks consisted primarily of dragon fly nymphs.

Management Implications-Recommendations

Chick Mortality/Survival

-Parks Canada and the CWS continue to annually monitor number of nests, chicks produced and chicks fledged both within and adjacent to WBNP.

-The CWS continue to work closely with the Governments of the NWT, First Nations, Alberta, Saskatchewan and Manitoba and continue to place high priority on the migration corridor and protection of staging areas of whooping cranes and the protection of the cranes through education and enforcement.

-It is recommended that whooping cranes in and around WBNP be allowed the opportunity to raise both young and that removal of eggs for management purposes only occurs to enhance/augment the diversity of genetics for captive facilities. Allowing the environment to determine which of the siblings survive will result in chicks being recruited into the next generation that are most capable of adapting to their changing surroundings.

Habitat Protection

- The continued protection of the ecological integrity of the whooping crane population and their summer habitat within WBNP be given the highest priority in wildlife management.

-Parks Canada should allow only activities that are consistent with a Zone1 while the cranes are on their nesting grounds.

-Parks Canada should inform the chairperson of the Canadian Whooping Recovery Team when a fire occurs within the nesting grounds and discuss appropriate management actions.

-Parks Canada and the Canadian Wildlife Service (CWS) should work towards developing a habitat suitability index (HSI) model to apply to the nesting and potential nesting wetlands within and adjacent to wetlands in WBNP. Data for the HSI should be derived using information from this study on habitat use and movements, from Timoney's (1997) nesting habitat study, and from Sotiropoulous's (2002) food web study.

-Parks Canada along with the CWS, Government of the Northwest Territories and First Nations should work towards establishing Memorandums of Agreement and Understanding with regard to habitat protection in areas where the whooping cranes already nest outside of WBNP and where they may expand in the future.

Water monitoring

-The hydrological regime plays a critical role in the whooping crane nesting area. The three main rivers/creeks that flow through the nesting area play an important role in recharging the ponds with water, fish and aquatic invertebrates. Parks Canada and the CWS should continue to annually monitor water levels, and water quality of the Preble, Sass and Klewi Rivers.

-Parks Canada should not allow activities that may reduce stream flows or inhibit movement of fish or aquatic invertebrates on the creeks and rivers that flow through the nesting ponds. Any road/culvert maintenance should occur during times when the cranes are not on their nesting grounds, after September.

-Parks Canada and the CWS should conduct periodic water quality testing at the north end of the nesting area (Nyarling River) and to the north of the park boundary in a newly occupied territory. The concern in this area would be from any lead/zinc tailings that may be seeping into the ground water from the abandoned Pine Point Mine.

-Parks Canada along with CWS should establish a contingency plan in the case of a toxic spill occurrence along Highway 5 that is close to the main creeks and rivers that flow through the nesting grounds.

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Appendix I

Table 4-37: Environmental variables sampled in random and feeding ponds.

	Random		**Feeding**		P value
Variable	Mean (n)	SE	Mean (n)	SE	
1 m from shore (cm)	9.51 (94)	0.95	13.13 (94)	1.05	*(P = 0.003)
5 m from shore (cm)	19.94 (94)	1.06	26.16 (94)	1.39	*(P = <0.001)
Center of pond (cm)	27.28 (94)	1.16	35.65 (94)	1.52	*(P = <0.001)
Pond temperature (^{0})	21.3 (94)	0.1	20.1 (94)	0.1	*(P = <0.001)
Pond area (ha)	0.77 (94)	0.2	1.1 (94)	0.2	*(P = 0.012)
Pond perimeter (m)	382.9 (94)	35.7	582.9 (94)	50.8	*(P = <0.001)
Pond Shape (area/perimeter)	0.13 (94)	.01	0.13 (94)	.01	(P = 0.425)
Exposed shore (m)	1.1 (94)	0.3	0.43 (94)	0.094	*(P = 0.007)
Area of Islands in ponds (ha)	0.04 (10)	0.01	0.084 (11)	0.03	(P = 0.398)
Dist. To Creek (m)	436.4 (94)	37.4	369.3 (94)	40.8	*(P = 0.034)
Scirpus validus (%)	9.6 (54)	1.4	16.9 (77)	1.5	*(P = <0.001)
Typha latifolia (%)	1.7 (13)	.1	5.7 (32)	1.1	*(P = 0.015)
Carex sp. (%)	4.1 (35)	.9	5.9 (36)	1.0	(P = 0.448)
Emergents (%)	18.93 (74)	1.98	29.76 (92)	2.0	*(P = <0.001)
DO (mg/L)	9.10 (94)	0.25	8.46 (94)	0.21	*(P = 0.015)
PH	7.72 (94)	0.06	7.42 (94)	0.05	*(P = <0.001)
Conductivity (µs/cm)	2384.08 (88)	163.48	2185.85 (87)	118.89	(P = 0.718)
Salinity (ppt)	1.36 (64)	0.11	1.24 (66)	0.09	(P = 0.725)

Total Phosphorous (ug/L^{-1})	29.73 (48)	2.54	25.55 (48)	2.29	**(P =0.070)
Chlorophyll *a* (ug/L)	5.3 (44)	1.86	3.51 (44)	0.71	(P = 0.634)

(Mann-Whitney Rank Sum Test Statistic).

P value significant at p = 0.05 *, at p = 0.10 **

Table 4-38: Fish, amphibians, and invertebrates caught in random and feeding ponds with minnow traps. (Mann-Whitney Rank Sum Test Statistic)

	Random Ponds				Feeding Ponds				
Taxa	# traps with Taxa	Total caught 940 trap days	Mean/ Minnow Trap	SE	# traps with taxa	Total caught 940 trap days	Mean/ Minnow Trap	SE	P value
Culaea inconstans	223	3291	3.5	0.4	484	9250	9.8	0.8	*P = <0.001
Dace sp.	101	3139	3.3	0.6	333	7859	8.4	0.8	*P = <0.001
Pimephales promelas	23	83	0.09	0.02	50	205	0.2	0.04	P = 0.281
Ranidae	49	119	0.1	0.02	39	162	0.2	0.03	P = 0.709
Corixidae	86	130	0.1	0.02	46	68	0.1	0.01	P = 0.92
Notonectidae	87	114	0.1	0.01	86	107	0.1	0.01	P = 0.111
Anisoptera	336	653	0.7	0.04	348	603	0.6	0.04	P = 0.14
Trichoptera	17	18	0.2	.005	20	21	0.02	0.01	P = 0.905
Lestidae	6	6	0.006	0.003	6	8	0.01	0.004	P = 1.00

Dytiscidae	224	423	0.4	0.04	154	235	0.2	0.02	*P = 0.003
Lethocerus sp.	58	66	0.07	0.01	83	98	0.10	0.01	P = 0.318
Lymnaeidae	224	428	0.4	0.04	175	249	0.3	0.02	*P = 0.026
Planorbidae	37	37	0.04	0.01	95	141	.15	0.02	*P = 0.015

Table 4-39: Fish, amphibians, and invertebrates caught in random and feeding ponds using invertebrate traps (5 traps in each pond in 1997, 10 in 1998 and 1999). (Mann-Whitney Rank Sum Test Statistic).

	Random Ponds				**Feeding Ponds**				
Taxa	# traps with Taxa	Total caught 805 trap days	Mean/ invert trap	SE	# traps with Taxa	Total caught 810 trap days	Mean/ invert trap	SE	P value
Culaea inconstans	109	348	0.4	0.07	230	1104	1.4	0.2	*P = <0.001
Dace sp.	29	101	0.1	0.03	86	426	0.5	0.1	*P = <0.015
Pimephales promelas	na	na	Na	na	Na	na	Na	na	Na
Ranidae	35	68	0.1	0.02	19	25	0.03	0.01	P = 0.482
Corixidae	161	592	0.7	0.1	126	333	0.4	0.05	P = 0.493
Notonectidae	46	55	0.1	0.1	62	83	0.2	0.1	P = 0.125
Anisoptera	92	116	0.1	0.01	112	144	0.2	0.02	P = 0.396
Trichoptera	8	8	0.001	0.01	8	10	0.01	0.05	P = 0.999

Lestidae	22	35	0.04	0.01	23	112	0.1	0.04	P = 0.959
Dytiscidae	59	83	0.1	0.01	53	119	0.1	0.03	P = 0.817
Lethocerus sp.	4	4	na	na	7	8	na	na	Na
Lymnaeidae	163	280	0.3	0.03	165	229	0.3	0.02	P = 0.929
Planorbidae	65	92	0.2	0.1	84	101	0.2	0.1	P = 0.445

Table 4-40: Snails counted in random and feeding ponds (half placed in open water half in emergent vegetation if vegetation present).

Gastropoda	# of quadrats with Gastropoda	# identified 564 quadrats	mean/ quadrat	SE	# of quadrats with Gastropoda	# identified 564 quadrats	mean/ quadrat	SE	P value
Lymnaeidae	92	140	0.25	0.03	98	148	0.26	0.04	P = 0.80
Planorbidae	19	23	0.04	0.01	33	50	0.09	0.02	P = 0.47

Table 4-41: Water depths of ponds without specific types of emergent vegetation compared with ponds with specific types of emergent vegetation (water depth at center of pond).

	None		**Emergents**		
Emergents	Mean	SE	Mean	SE	P value
Scirpus validus	29.83 (56)	1.96	32.18 (132)	1.9	**P = 0.073
Typha latifolia	29.44 (143)	0.94	37.89 (45)	2.8	*P = 0.003
Carex spp.	29.73 (116)	1.08	34.26 (72)	1.2	**P = 0.085

Total emergents	24.6 (22)	1.9	32.4 (166)	1.1	*P = 0.008

Table 4-42: Characteristics of ponds where fish were not caught and where fish were caught. (Mann-Whitney Rank Sum Test Statistic).

	No fish caught		**Fish caught**		
Pond Variables	**Mean**	**SE**	**Mean**	**SE**	P value
Water depth 1 m from shore	8.23 (85)	0.8	13.7 (103)	1.1	*P = <0.001
Water depth 5 m from shore	18.8 (85)	0.9	26.4 (103)	1.4	*P = <0.001
Water depth center of pond	26.2 (85)	1.1	35.7 (103)	1.45	*P = <0.001
Pond temperature	21.4 (85)	0.5	20.1 (103)	0.4	*P = 0.026
Pond area	0.62 (85)	0.1	1.1 (103)	0.2	P = 0.208
Pond perimeter	427.8 (85)	45.4	528.4 (103)	44.1	**P = 0.064
Exposed shoreline	0.83 (85)	0.1	0.7 (103)	0.2	**P = 0.078
Distance to Creek	464.0 (85)	41.3	359.5 (103)	36.7	*P = 0.010
Scirpus validus	11.6 (85)	1.7	14.6 (103)	1.3	*P = 0.009
Typha latifolia	2.8 (85)	0.9	4.4 (103)	0.9	**P = 0.077
Carex sp.	3.0 (85)	0.8	6.6 (103)	1.1	*P = 0.049
Total emergents	17.4 (85)	2.1	25.5 (103)	1.9	*P = <0.001
Dissolved Oxygen	9.4 (85)	0.2	8.3 (103)	0.23	*P = 0.004
PH	7.7 (85)	0.06	7.42(103)	0.05	*P = <0.001
Conductivity	2255.4 (85)	175.7	2312.1 (93)	111.8	P = 0.136
Salinity	1.3 (61)	0.1	1.4 (71)	0.1	**P = 0.065
Total Phosphorus	30.2 (53)	2.0	24.5 (43)	2.3	*P = 0.045

Chlorophyll *a*	3.6 (50)	0.8	5.7 (38)	2.0	P = 0.533

Table 4-43: Mean number of amphibians and invertebrates caught in ponds where fish were not caught, and where fish were caught using Minnow traps.

	No fish caught		**Fish caught**		
Biotic Variable	mean/trap 850 trap days	SE	mean/trap 1030 trap days	SE	P value
Ranidae	0.2	0.03	0.14	0.03	P = 0.263
Corixidae	0.2	0.02	.05	0.01	*P = 0.001
Notonectidae	0.2	0.01	0.11	0.03	P = 0.121
Anisoptera	0.9	0.05	0.5	0.03	*P = <0.001
Trichoptera	0.02	0.01	0.02	.01	P = 0.890
Lestidae	0.01	0.003	0.007	0.003	P = 0.900
Dytiscidae	0.6	0.04	0.17	0.02	*P = <0.001
Lethocerus sp.	0.07	0.01	0.102	0.01	P = 0.321
Lymnaeidae	0.5	0.04	0.2	0.02	*P = <0.001
Planorbidae	0.09	0.01	0.1	0.01	P = 0.998

Table 4-44: Mean number of amphibians and invertebrates caught in ponds where fish were not caught, using invertebrate/activity traps. .(Mann-Whitney Rank Sum Test Statistic).

	No fish caught		**Fish caught**		
Biotic Variable	Mean/trap 735 trap days	SE	Mean/trap 870 trap days	SE	P value
Ranidae	0.1	0.02	0.03	0.01	P = 0.325
Corixidae	0.8	0.1	0.4	0.01	*P = <0.001
Notonectidae	0.1	0.01	0.07	0.01	P = 0.278
Anisoptera	0.17	0.02	0.16	0.02	P = 0.266
Trichoptera	0.005	0.002	0.02	0.01	P = 0.772
Lestidae	0.06	0.02	0.1	0.03	P = 0.852
Dytiscidae	0.1	0.02	0.13	0.02	P = 0.994
Lethocerus sp.	0.007	0.003	0.01	0.003	P = 0.997
Lymnaeidae	0.4	0.04	0.25	0.02	P = 0.110
Planorbidae	0.13	0.02	0.11	0.01	P = 0.816

Table 4-45: Comparison of amphibians and invertebrates caught in ponds where fish were caught and in ponds where fish were not caught using both minnow and invertebrate/activity traps combined. (Mann-Whitney Rank Sum Test Statistic).

Biotic Variable	**P value**
Ranidae	(P = 0.137) no difference was detected in the number of Ranidae caught in ponds where fish were caught and ponds where no fish were caught
Corixidae	(P = <0.001) significantly more Corixidae were caught in ponds where no fish were caught
Notonectidae	(P = 0.062) difference at the p = 0.100 level, slightly more Notonectidae in ponds where no fish were caught
Anisoptera	(P = <0.001) significantly more Anisoptera in ponds where no fish were caught
Trichoptera	(P = 0.763) no difference was detected in the number of Trichoptera caught in ponds where fish were caught and ponds where no fish were caught
Lestidae	(P = 0.819) no difference was detected in the number of Lestidae caught in ponds where fish were caught and ponds where no fish were caught
Dytiscidae	(P = <0.001) significantly more Dytiscidae were caught in ponds where no fish were caught
Lethocerus sp.	(P = 0.453) no difference was detected in the number of *Lethocerus* sp. caught in ponds where fish were caught and ponds where no fish were caught
Lymnaeidae	(P = <0.001) significantly more Lymnaeidae were caught in ponds where no fish were caught
Planorbidae	(P = 0.878) no difference was detected in the number of Planorbidae caught in ponds where fish were caught and ponds where no fish were caught