The University of Calgary

Management of Captive Whooping Cranes (Grus americana) to Improve Breeding Behaviour and Success

By Jennifer L. White

A Master's Degree Project submitted to the
Faculty of Environmental Design
in partial fulfillment of the requirements
for the degree of
Master of Environmental Design (Environmental Science)

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Abstract

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Since 1941, when the severely endangered Whooping Crane reached a global population low of only 15 individuals in a single migrating flock, conservation efforts to recover the species have met with moderate success. The migratory flock remains today the only wild self-sustaining viable population of Whooping Cranes. Currently, numbers are increasing (180 in 1999), and several conservation efforts have been undertaken to increase the population of Whooping Cranes in North America. Captive breeding programs have been established at three locations including the Devonian Wildlife Conservation Centre in Calgary, Alberta. Captive breeding programs have met with only modest success; the main problem encountered is poor reproductive performance for which causal factors remain poorly understood. I undertook a project to review and compare captive breeding practices at three facilities and to provide recommendations to improve captive breeding success. The objectives of the study were the following: to compile and summarize historic and current information on the status of the Whooping Crane in Alberta; to evaluate the behaviour of captive Whooping Cranes at the Devonian Wildlife Conservation Centre (DWCC) breeding facility during the 1999 breeding season; to compare breeding success, husbandry practices, and facility design at the DWCC with those at the United States Government Services Patuxent Wildlife Research Center facility in Laurel, Maryland, and the International Crane Foundation facility in Baraboo, Wisconsin; to develop a comprehensive list of factors that potentially affect the breeding of Whooping Cranes in captivity; and to offer recommendations to DWCC that may enhance captive breeding success.

Keywords: Whooping Crane, *Grus americana*, endangered species, captive breeding management, facility design

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Preface

On September 30, 1950, in the preface to the first comprehensive research report dedicated to the Whooping Crane, Robert Porter Allen wrote the following:

> We cannot limit our thinking to a mere numerical appraisal. Each one of these great birds is far more than simply "number one" or "number thirty-five." Each of them is a tremendous potentiality. When you sit crouched in a blind and watch an adult Whooper stride close by you, his being arrogant and imposing, you feel the presence of a strength and a stubborn will to survive that is one of the vital intangibles of this entire situation. Certainly it cannot be overlooked. We have a strong conviction that the Whooping Crane will keep his part of the bargain and will fight for survival every inch of the way. What are we going to do to help? Here... is the challenge, here is the job that must be done. (Allen 1952)

The challenge has been posed over the last half century to many different generations of scientists, crane biologists, environmentalists, and naturalists. I have accepted this challenge and the results of my effort follow.

Jennifer White, April 17, 2000
University of Calgary
Faculty of Environmental Design

1.0 Introduction

"What is the meaning of all that cranes do? Words alone will not suffice to share the wonders of this elegant, graceful bird... Cranes are a wild wonder. They bring understanding of endurance, balance, tolerance, and compassion. They are reason to celebrate life!"

Janet Flynn, 1999

1.1 Introduction

Once widely distributed throughout the Great Plains region of North America, the Whooping Crane (Grus americana) nearly became extinct in the twentieth century as a result of market hunting, habitat destruction, and human settlement (Allen 1959). By the middle of the twentieth century, only one wild population of Whooping Cranes remained, a migratory flock that wintered at the Aransas National Wildlife Refuge (ANWR) in Texas and bred in Wood Buffalo National Park (WBNP) in Alberta and the Northwest Territories. The Whooping Crane has been extirpated from the remainder of its natural breeding and wintering ranges. The most critical issue in the management of Whooping Cranes is low population size. The population rebounded from only 15 individuals in 1941 to about 180 individuals in the wild migratory population, but still remains extremely vulnerable because of a number of anthropogenic, biological, and environmental factors threatening the stability and overall viability of the species (Allen 1959).

In addition to protecting the last remaining wild migratory population, the international recovery program has undertaken captive breeding projects in several locations in Canada and the United States. It began in 1967, when the Canadian Wildlife Service began removing 'surplus' Whooping Crane eggs from wild nests in Wood Buffalo National Park and transporting them to the U. S. Government Services Patuxent Wildlife Research Center [Patuxent] in Laurel, Maryland (Loftin 1995). About 20 years later, a number of Whooping Cranes were transferred to the International Crane Foundation in Baraboo, Wisconsin [ICF]. The Devonian Wildlife Conservation Centre at the Calgary Zoo [DWCC] received its first Whooping Cranes for captive breeding in 1992.

The San Antonio Zoo in San Antonio, Texas currently holds two pairs of Whooping Cranes, which have been on display for several years (San Antonio Zoo 1999). The Audubon Zoo in New Orleans, Louisiana has been holding one pair of Whooping Cranes off display in their Species Survival Center, since December 1998 (Audubon Zoo 1999). Because of the relatively small numbers of Whooping Cranes kept in both the San Antonio Zoo and the Audubon Zoo, their populations will not be included in the comparison of captive breeding success and practices for the purposes of this master's degree project. Instead, the focus will be on Patuxent, the ICF, and the DWCC, who together hold as of November 1999 approximately 130 Whooping Cranes in their captive breeding programs (T. Stehn pers. comm.).

These programs have met with modest success; however the main obstacle encountered is low reproductive success resulting from incomplete understanding of behaviour, husbandry, and facility design. It was only in 1975, after having had cranes in captivity for eight years, that the first pair bred in captivity, and that was with the application of artificial insemination (Loftin 1995). It is critical that both the captive and wild populations are managed in such a way to promote successful breeding, maximize genetic diversity, and ensure that numbers continue to steadily increase. The purpose of this thesis extends beyond the philosophical reasons of whether we should or should not continue to attempt to preserve rare species such as the Whooping Crane through the use of captive breeding programs. However, several of the arguments for and against captive breeding are discussed.

As recently as several decades ago, the lives of animals in zoos could be described as "solitary, poor, nasty, brutish, and short" (Tudge 1991). Today, however, zoos are much more capable of providing animals with an improved quality of life (Tudge 1991). The current purpose of most zoos is becoming increasingly disparate from the initial goal of merely displaying animals for a paying public, and is instead moving towards playing a major role in the field of animal conservation, particularly through the institution of captive breeding programs (Tudge 1991). Zoos find themselves reinvented from the original amusement parks intended to display animals for the purpose of human entertainment, to wildlife conservation parks with an emphasis on research, public education, and species survival (Jamieson 1995). In fact, many zoos balk at the idea of being called a 'zoo,' which can imply crowding, confusion, and chaos, and prefer to be referred to as 'conservation parks' (Maple 1995).

Most North American zoos are members of the American Zoological Association, and as such have adopted four basic directives: conservation, education, science, and recreation (Maple et al. 1995). The Calgary Zoological Society has incorporated these four directives into their mission statement (Calgary Zoo 2000). The major emphasis in most conservation centres has been on improving knowledge of species-specific nutritional requirements, preventing disease, and simulating wild conditions to allow for potential future reintroduction (Tudge 1991).

The reasons for resorting to captive breeding to protect a declining species are rooted in the belief that each species has an intrinsic and inherent value (Tudge 1991). It is my position that if human actions are responsible for the decline of a species, then humans should also be responsible for attempting to reverse the damage by protecting the species at all costs. In many instances, simply ceasing the activity that caused the species' population decline is not enough, and in this way we come to retaining animals in captivity for the purposes of captive breeding for further releases to the wild.

The essential goal of captive breeding programs is to ensure that the animals are content, healthy, and breeding well (Tudge 1991). There is no simple relationship between animals' reproduction and welfare: if an animal is breeding well in captivity, we cannot assume that it is content, nor can we assume if an animal is not breeding that it is not content (Tudge 1991). There are myriad species-specific requirements associated with a potential mating event, and if these conditions are not met, mating will not take place (Tudge 1991).

Captive breeding has been conducted in the past for many different reasons, including to produce rare and valuable animals for commercial sale, to produce game animals to be released and hunted, and to save animals that are threatened by extinction from the wild (Loftin 1995). The purpose of this thesis is to address only captive breeding for species survival and restoration reasons.

Captive breeding should not be the only consideration for species restoration and preservation, but can be one tool considered when efforts to restore and preserve habitats have failed (Wagner 1995). The strongest argument in support of captive breeding is that in some instances, there is simply no alternative (Loftin 1995). Without human intervention, some species face certain extinction in the wild from habitat loss, genetic inbreeding, environmental contamination, epidemic diseases, hunting, and myriad other causes (Loftin 1995). As an attempt to prevent further species extinction, many zoos and aquaria become the last potential refuge for species at risk (Wagner 1995).

In the case of the Whooping Crane, with only 15 birds remaining in a single migratory population, the chances of survival were very slim without initiating a captive-breeding program. However, keeping animals within their native habitats is considered to be the most parsimonious solution to conservation issues (Conway 1983). Only when that is not possible, should zoos and captive breeding programs be considered as a last resort for the survival of the species (Conway 1977, Conway 1983). As numbers increase, many believe that zoos should change their focus from *ex situ* conservation to *in situ* or field-based conservation attempts (Balmford et al.1996).

Carpenter and Derrickson (1981) developed a list of the following guidelines to be considered prior to initiating a captive-breeding program:

- the probability of extinction of the species,
- the effectiveness of efforts to manage the wild populations,
- the potential to address basic research and species management questions,
- the potential for future reintroduction to the wild,
- the applicability of techniques developed to other endangered species,
- the availability of captive individuals, and
- the availability of adequate facilities, staffs, and funds to initiate and sustain the breeding program (Carpenter and Derrickson 1981).

The wild Whooping Crane population was so diminished that few would disagree that captive breeding was an important way to ensure the survival of the species. While the breeding and wintering grounds had been protected for a number of years, the 4500km-migration route flown twice a year leaves the population extremely vulnerable. At the time of initiation of the captive-breeding program, it was thought that captive-reared birds would be used to first supplement the wild flock, and when numbers became great enough, to establish new migratory flocks (Kuyt 1996b). Because there are many endangered and threatened species of cranes in the world, valuable husbandry and propagation techniques developed for the Whooping Crane could be used to help conserve other crane species. The captive breeding program had the financial commitment of the Canadian and U. S. governments, and so plans began to create the first captive breeding flock in Laurel, Maryland at the Patuxent Wildlife Research Center.

One of the major obstacles to captive breeding success is that zoo facilities are often poorly designed for propagation purposes and the breeding requirements of many species are often improperly understood (Conway 1983). Captive animals are often stressed and will not breed (Wuichet and Norton 1995). It is important to remember, though, that animals in the wild face different stresses than animals in captivity, and both groups of animals are subjected to stress on a daily basis (Wuichet and Norton 1995).

There are many problems associated with captive breeding of animals, including failure to provide adequate habitat, inability to raise populations above the level of viability, excessive inbreeding genetic depression, and the difficulty of behaviourally reshaping captive-bred animals for release to the wild (Wagner 1995). "The predominant goal of [captive breeding] programs is not to restore animal populations to their original conditions but to reshape them so they can exist in a thickly populated, heavily developed, economically expanding nation." (DeBlieu 1991)

Captive breeding programs reshape animals both behaviourally and genetically (Loftin 1995). Captive breeding programs are the result of an autecological or single-species management approach rather than an ecosystem-based approach (Loftin 1995). It can be argued that change is a natural process, and since humans have irrevocably changed the environment, it is perfectly natural for humans to use management tools such as captive breeding programs to help animals adjust and adapt to the changed ecosystems (Loftin 1995).

The key to successful captive breeding programs is not to simply rear the progeny of pairs in captivity, but to be able to rear the progeny of that progeny, and so on, and for animals at any of those stages to be behaviourally fit to withstand the rigors of the environment following release (Conway 1983). It is necessary for a captive breeding program "to produce not only young birds, but also publications" (Nichols 1977). Efforts to conserve species such as the Amazon parrot have been hampered by the fact that birds are housed in many different locations and communication among aviculturists is limited (Nichols 1977).

Przewalski's horse, the California condor, the North American red wolf, the Arabian oryx, and the European wisent are all species that at one time had become extinct in the wild and existed solely in captivity, and were later restored to the wild after captive breeding program releases (Loftin 1995, Wagner 1995). Many species, including peregrine falcons, black-footed ferrets, and golden lion tamarins have been near-extinction in the wild and have benefited from population augmentation and extension of species ranges by release of captive-bred animals (Wagner 1995).

The Whooping Crane is not the only species that is a challenge to breed in captivity. Peregrine falcons bred unpredictably in captivity for years until a species-specific connection between rearing method and breeding success was determined (Cade and Fyfe 1977, Cade 1990, Weaver and Cade 1991). Efforts were placed on the breeding of those birds whose rearing method had been appropriate, and the captive breeding programs were subsequently incredibly successful (Cade and Fyfe 1977, Cade 1990, Weaver and Cade 1991).

Aviculture has evolved from the art and hobby of breeding captive birds to a science evolving rapidly with the technology to support the programs (Conway 1983). Captive propagation of Whooping Cranes benefits from the improvement of avicultural techniques including inducement of additional egg clutches, artificial insemination, artificial and surrogate incubation of eggs, foster parenting, hand-rearing, and supportive feeding (Conway 1983). Aviculturists use the technique of inducing replacement clutches on many different species of birds, including Whooping Cranes (Conway 1983). The first successful cryopreservation of any wild bird's semen was that of the Whooping Crane, at Patuxent Wildlife Research Center in the early 1980s (Conway 1983).

Conway (1983) identified clear directions for future research into captive breeding programs to include development of optimal methods for sperm collection and evaluation, synchronization and recognition of synchronization of both individuals in a mated pair, analysis of environmental effects including food, temperature, space, and light regimens, and determination of timing of ovulation and its relation to internal and external stim uli.

Whooping Crane research in the past 15 years has addressed many of these issues, and yet many factors affecting Whooping Crane breeding in captivity still remain a mystery.

1.2 Purpose and Objectives

Although managers of the captive breeding programs share information on breeding behaviour, husbandry, and facility design, differences exist between facilities in these aspects of their programs. In addition, the experience and knowledge of managers varies and has to date not been compiled into a synthesis resource document dedicated to the unique needs of the Whooping Crane, nor has there been a comprehensive evaluation of practices. The purpose of my project was to review and compare captive breeding practices at the three facilities and to provide recommendations to improve captive breeding success.

Five major objectives were defined for this Master's Degree Project.

The first major objective was to compile and summarize the status and natural history of the Whooping Crane in Alberta.

The second major objective was to evaluate the behaviour of captive Whooping Cranes at the Devonian Wildlife Conservation Centre (DWCC) breeding facility near Calgary. It was important to understand behaviour prior to discussing methods to potentially improve and or enhance breeding success.

The third major objective was to compare and contrast the breeding success and management practices of the Devonian Wildlife Conservation Centre Whooping Cranes with the following facilities:

a) the United States Government Services Patuxent Wildlife Research Center facility in Laurel, Maryland, and
b) the International Crane Foundation facility in Baraboo, Wisconsin.

The fourth major objective for this project was to develop a comprehensive list of factors that potentially affect the breeding of Whooping Cranes in captivity.

Finally, this information was used to generate management recommendations on husbandry practices and facility design for the Devonian Wildlife Conservation Centre of the Calgary Zoo, to improve breeding behaviour and success of their captive Whooping Cranes.

1.3 Approach

An evaluation of the current behaviour (breeding and otherwise) of the DWCC Whooping Cranes was conducted from late March to mid May 1999. Behavioural observations were recorded on a daily basis for six weeks. As well, I was given access to three years of previous behavioural observation data that was collected by Calgary Zoo 'docent' volunteers and DWCC staff, under the direction of Dwight Knapik. A detailed methodological description of the fieldwork is given in section 3.2 "Methods."

In addition to comparing pairs at the Devonian Wildlife Conservation Centre, the behaviour of these cranes was qualitatively evaluated by managers at other facilities through the use of key informant interviews. The degree of breeding success (successful mating events, number of eggs produced, number of fertile eggs) was used as criteria for evaluating the behavioural competence of pairs at each facility. Detailed behavioural data collected at the DWCC was used to interpret differences between facilities.

The breeding behavioural competence of Whooping Cranes may be influenced by captive rearing practices, diet, health status, imprinting, extraneous disturbances, selection of mates and determination of pair bonds, individual life histories, pedigree or genetic management, security from predators, physical hazards within their captive enclosures, and myriad other factors. These factors were defined for each crane at the Devonian Wildlife Conservation Centre in order to deduce influences of husbandry practices on breeding success. The success and problems related to husbandry will be described for each of the three facilities.

The suitability of captive breeding environments was evaluated by describing and comparing the physical design of the three captive breeding facilities. Factors that were investigated included pen size, shape, and height, proximity of the enclosure to other crane species, proximity of the enclosure to other Whooping Cranes, inclusion of ponds within the pen, terrain complexity, vegetation, visual barriers, and potential hazards to crane health and safety. This descriptive component involved a qualitative evaluation to define characteristics of suitable breeding enclosures. The behavioural requirements specific to breeding were taken into consideration: for example, adequate room to dance and display, and protection for nests from predators, are of paramount importance.

An extensive review of the published and unpublished literature was undertaken from January to August of 1999. Key informant interviews with Whooping Crane keepers, aviculturists, and managers were conducted to determine other factors that may influence breeding in captivity. This information was combined into a master list of factors that can affect the breeding behaviour and success of captive Whooping Cranes, and in turn presented at the North American Crane Workshop, held in Baraboo, Wisconsin from September 18-21, 1999. Final revisions were made to the list, which is outlined in the discussion, section 4.4.3, "Development of a List of Factors Affecting Breeding Success." This list became the basis for management and future research recommendations described in section 5.Recommendations.'

1.4 *Organization of Thesis*

The remainder of this thesis is presented in four separate chapters. Chapter two discusses the natural history and status of the Whooping Crane in Alberta and within North America. Included are discussions of habitat, conservation biology, distribution, population size and trends, limiting factors, status designations, and recent management endeavours.

Chapter three is a detailed analysis of behaviour at the Devonian Wildlife Conservation Centre. It contains details about the current status of the captive Whooping Cranes at the facility, based on an evaluation of the 1999 breeding season behaviour.

Chapter four presents an evaluation of Whooping Crane captive breeding programs. It compares breeding successes and management practices at DWCC with breeding programs in other North American facilities as well as with breeding success of the wild population. The comprehensive list of factors that may affect the breeding of Whooping Cranes in captivity is included in this chapter.

The intervention component of this Master's Degree Project is contained within the fifth and final chapter. This chapter follows the evaluation of factors that can affect the breeding of Whooping Cranes in captivity (Chapter 4) with a discussion of the most appropriate strategies for improving captive breeding success. Management recommendations for changes to husbandry practices, facility design and future research strategies are provided for the Devonian Wildlife Conservation Centre of the Calgary Zoo to consider.

2.0 The Natural History and Status of the Whooping Crane

"The sight of a Whooping Crane in the air is an experience packed with beauty and drama. We see the broad sweep of the great wings in their stiff, almost ponderous motion, the flash of sunlight on the satin white plumage."

Robert Porter Allen, 1952

2.1 *Introduction*

The Whooping Crane nests inside Wood Buffalo National Park in the Northwest Territories and the adjacent area in extreme northern Alberta (Johns 1998b). Historically, there are believed to have been between 1300 and 1400 Whooping Cranes (Grus americana) in North America (Allen 1952), however populations began to decline dramatically in the latter 19^{th} century because of over-hunting, habitat loss, and habitat degradation. The population reached a low of only 15 individuals, remaining in a single migratory flock. Because of heightened conservation efforts in the latter half of the twentieth century, the population stabilized and is now increasing slowly. There are approximately 180 individuals in the migratory flock that breeds in Wood Buffalo National Park.

The Whooping Crane has been a 'Red-Listed' species in Alberta since 1991 (Alberta Wildlife Management Division 1996), meaning that the species is currently at risk of extirpation within the province. As well, the Alberta Wildlife Act lists the Whooping Crane as 'endangered' (Wildlife Act 1984). The species was also listed as 'endangered' nationally in Canada by COSEWIC in 1978, the first year that species status designations were made (RENEW 1998). The Whooping Crane remains on the COSEWIC list of endangered species today. Although the number of Whooping Cranes is increasing, the species is still vulnerable because of its relatively small population size.

The Whooping Crane has been widely studied for the past half-century, and there is much information available on its biology and history. The purpose of this chapter is to compile and summarize up-to-date information and to update the current status of the species within Alberta. This chapter reviews historical and current information on the Whooping Crane.

2.2 *Habitat*

The Whooping Crane has very extensive yet specific habitat requirements on its wintering and breeding grounds, and along its migratory route. Current nesting areas are in poorly drained areas where muskeg joins boreal forest (Allen 1956, Novakowski 1966, Kuyt 1981, Meine and

Archibald 1996, Timoney 1999). Historically, cranes were believed to have nested in large isolated marshes in prairie and aspen park land (Gollop 1978).

Whooping Cranes nest primarily in bulrush, sedges or other emergent vegetation in shallow areas of still water, either ponds, small lakes, or wet meadows (Kuyt 1995). The wetlands are extremely shallow and often separated from one another by narrow ridges, 60-90cm in height, supporting dense thickets of Willows (Salix species), Black Spruce (Picea mariana), Dwarf Birch (Betula glandulosa), and Tamarack (Larix occidentalis) (Allen 1956).

Wintering grounds on the Blackjack Peninsula of the Gulf of Mexico consist of an outer peninsula surrounded by tidal marshes and uplands marked with long, narrow ponds (Johnson 1976). This area is dominated by Salt Grass (Distichlis spicata), Saltwort (Batis maritima), Glasswort (Salicornia species), and Salt-Flat Grass (Monanthochloe littoralis) as well as Cordgrass (Spartina species) (Stevenson and Griffith 1946). In winter, the majority of Whooping Cranes use brackish bays, estuarine marshes, and tidal flat areas dominated by aquatic vegetation (Allen 1952, Allen 1956, Labuda and Butts 1979, Stehn and Johnson 1987). Whooping Cranes can also use upland habitat, especially when it has been flooded or undergone prescribed-burning (Hunt 1987).

While migrating, Whooping Crane habitat requirements can include croplands and grain fields, large or small prairie freshwater marshes, the margins of lakes and reservoirs, and submerged sandbars in rivers (Howe 1989, Johns 1992, Johns et al. 1997, Johnsgard 1991, Kuyt 1992).

It is unknown if Whooping Cranes remain at their current nesting grounds in Wood Buffalo National Park because it represents ideal breeding habitat or if they have been pushed further and further north to the fringe of their historical breeding range to find undisturbed habitat. Historical records, however, indicate that almost all recorded sightings of nesting areas were not in their current northern muskeg habitat but rather in the aspen parkland zone, the transitional belt that lies between plains and parklands throughout the Canadian prairies (Allen 1952). Many of the reasons for this shift from traditional to current nesting habitat are described in this chapter (discussed in section 2.6 "Limiting Factors").

2.3 *Conservation Biology*

The Whooping Crane is North America's tallest bird, with males approaching almost 1.5m in height and 2.5m in wingspan (Edwards et al. 1994, Peterson 1990). Males are generally larger than females, with average weights of 7.3 and 6.4kg, respectively (Erickson and Derrickson 1981). Cranes are sexually monomorphic birds, meaning that an individual's sex cannot be determined by the outside appearance. Adult plumage is snowy white with the exception of black primaries on the tips of the wings, and a bright red post-occipital patch (Allen 1952, Erickson and Derrickson 1981).

Whooping Cranes reach sexual maturity at approximately 5 years of age. Each pair builds a nest in an area averaging 4.1 km^2, but territories may be up to 47 km^2 (Kuyt 1981). Whooping Cranes usually nest at least 1km apart from an adjacent nest (Kuyt 1981), but nests have been recorded as close as 500m in dense nesting areas along the Klewi River and Preble Creek (B. Johns pers. comm.). Nesting occurs in marshes and nests are built of vegetation including bulrushes and sedge (Edwards et al. 1994). Whooping Cranes eggs are light brown to olive in colour with darker brown or purple blotches. Incubation is shared by both adults and lasts for 29-30 days (Edwards et al. 1994). Cranes usually have a clutch size of two eggs, although one to three eggs are possible. Only one young usually survives to maturity (Edwards et al. 1994). Juveniles vary in colour from rust to cinnamon (Peterson 1990) and are capable of flight at 80 to 90 days (Edwards et al. 1994).

Predation is a threat to all species, but particularly when endangered species such as Whooping Cranes are concerned, there exists the potential to have a great affect on abundance. Predation on eggs and recently hatched young can reduce the number of viable offspring produced in a season (B. Johns pers. comm.). Bobcat predation is the primary source of mortality for the Whooping Crane flock on the Kissimmee Prairie in Florida (US Fish and Wildlife Service 1998).

The diet of the omnivorous Whooping Crane consists primarily of molluscs, crustaceans, insects, minnows, frogs, and snakes while at the breeding grounds (Allen 1956, Novakowski 1966). Whooping Crane's winter diet consists of blue crabs, clams, fiddler crabs, shrimp, other aquatic invertebrates and small vertebrates, and plants (Allen 1952, Allen 1956, Labuda and Butts 1979, Stehn and Johnson 1987), and can also include foraging for acorns, snails, insects, and rodents when using more upland habitat (Hunt 1987).

Fall migration begins in late September, when the first birds begin leaving Wood Buffalo National Park (Johnsgard 1991). While migrating their diet shifts to include waste grains on agricultural lands such as barley and wheat (Meine and Archibald 1996, Johns et al. 1997) and they generally begin arriving in Aransas in late October (Johnsgard 1991). Spring migration begins in late March (Meine and Archibald 1996).

2.4 *Species Abundance and Distribution*

2.4.1 *Alberta*

Whooping Cranes in the remaining wild migratory population currently nest in Wood Buffalo National Park, in an area that spans the Alberta-Northwest Territories border. Several pairs nest in Alberta, immediately south of 60° N, but the majority of pairs nest in the Northwest Territories, immediately north of 60° N (Johns 1998b). These birds also pass through northeastern Alberta along their migratory route to and from the wintering grounds in the Aransas National Wildlife Refuge in Texas.

Historically, Whooping Cranes are known to have nested in northern and central Alberta, extending at least as far south as the Battle River (Salt and Salt 1976). They are believed to have had established breeding grounds in central Alberta near Killam, Whitford Lake, and Wainwright (Godfrey 1966). In 1977, a Whooping Crane nest was found 5km south of the Northwest Territories Border (Pinel et al. 1991). Several nests were observed within the Alberta portion of Wood Buffalo National Park again in 1978 and 1979 (Pinel et al. 1991). Prior to this finding, the last known nesting of Whooping Cranes within Alberta was in Wainwright in 1914 (Kuyt 1978). A lone Whooping Crane was sighted in Waterton Lakes National Park in southern Alberta in 1966, however historical records are poor and the probability exists that this sighting was a misidentification (Sadler and Myres 1976).

2.4.2 *Continental Range*

2.4.2.1 Wild Populations

Whooping Cranes are not currently living, nor are they historically believed to have existed, on a year-round basis in the province of Alberta. The Whooping Crane's breeding range is believed to have historically extended from the Arctic coast to Central Mexico and from the Atlantic seaboard to Utah, including throughout Alberta (Allen 1952, Gollop 1978, Edwards et al. 1994). In the latter half of the 19th and the early 20th century, the cranes' range shrank dramatically. At that time, the primary nesting areas were restricted to an extension from central Illinois, through northwestern Iowa, northwestern Minnesota, northeastern North Dakota, and then extended northwesterly through southwestern Manitoba and Southern Saskatchewan into east-central Alberta (Allen 1952, Gollop 1978, Edwards et al. 1994). By the 1890s, the Whooping Crane was extirpated from the US portion of its historical breeding range, and the last observation of nesting in the Canadian aspen parklands was in 1929 in south-central Saskatchewan (Meine and Archibald 1996).

Today, there exist three separate wild Whooping Crane populations in North America: the Wood Buffalo - Aransas migratory population, remnants of the experimental Sandhill Crane cross-fostered population in the Rocky Mountains of the United States, and a recently established experimental non-migratory population on the Kissimmee Prairie in Florida (Meine and Archibald 1996).

Of the three wild populations remaining in North America, only the migratory flock is currently self-sustaining (Meine and Archibald 1996). This flock of Whooping Cranes nests in Wood Buffalo National Park in Alberta and the Northwest Territories and winters on the Gulf of Mexico's lower Texas coast between Galveston and Corpus Christi (Edwards et al. 1994, Meine and Archibald 1996, Johnson 1976). A small, isolated, non-migratory flock remained in southwestern Louisiana, near White Lake until 1948, when the last surviving Whooping Crane from this flock was taken into captivity (Doughty 1989, Edwards et al. 1994, Meine and Archibald 1996). An experimental project from 1975 to 1989 attempted to re-introduce Whooping Cranes to the U. S. Rocky Mountains by placing Whooping Crane eggs in Sandhill crane nests at the Grays Lake National Wildlife Refuge; however these birds never reproduced successfully and the experiment was ceased (Meine and Archibald 1996, May 1992). The current focus of reintroduction efforts includes a proposed second migratory flock wintering in Florida and breeding in Wisconsin (G. Archibald pers. comm.) and a non-migratory flock currently being established on the Kissimmee Prairie in Florida (Nesbitt et al. 1997). The Florida Whooping Crane population is only now reaching sexual maturity and reproduction has not yet been recorded (M. Folk pers. comm., Meine and Archibald 1996).

The breeding range of the migratory flock of Whooping Cranes is restricted to a small portion of Wood Buffalo National Park approximately $80km^2$, extending along the Little Buffalo, Sass, Klewi, and Nyarling Rivers (B. Johns pers. comm.). The vast majority of breeding sites are north of 60° N in the Northwest Territories, with several pairs choosing to nest in Alberta (Kuyt 1993, Kuyt 1995, Johns 1998a). The southernmost nesting site ever observed is a pair breeding at 59 degrees 45minutes north, just within the province of Alberta (Kuyt 1993, Kuyt 1995, Kuyt and Goossen 1987). Nesting has been observed to occur in the large marsh areas surrounding the Little Buffalo River and its tributaries, the Nyarling, Klewi, and Sass Rivers, and Seton Creek (Kuyt 1993, Kuyt and Goossen 1987).

These birds winter on the Gulf coast of Texas, within the Aransas National Wildlife Refuge and adjacent areas (Stehn and Johnson 1987). During their 4500km migration in the spring and fall, Whooping Cranes pass through Texas, Oklahoma, Kansas, Nebraska, South Dakota, North Dakota, southwestern Manitoba, Saskatchewan, and Alberta (Gollop 1978). The Whooping Cranes fly to west-central Saskatchewan after leaving WBNP and begin their southward migration, where their migratory territory can include submerged sandbars in the Saskatchewan, Platte, Niobrar, and Red Rivers (Howe 1989, Kuyt 1992). The spring northward migration begins when the warm southeasterly winds begin flowing in the Gulf of Mexico, usually by the second week of April (Johnsgard 1991). The birds arrive in the Platte Valley of Nebraska where they remain for several days in a different staging area than the one used on the southward migration, roosting on the Platte River and feeding before proceeding to Saskatchewan and on to Wood Buffalo National Park (Johns 1992, Johnsgard 1991).

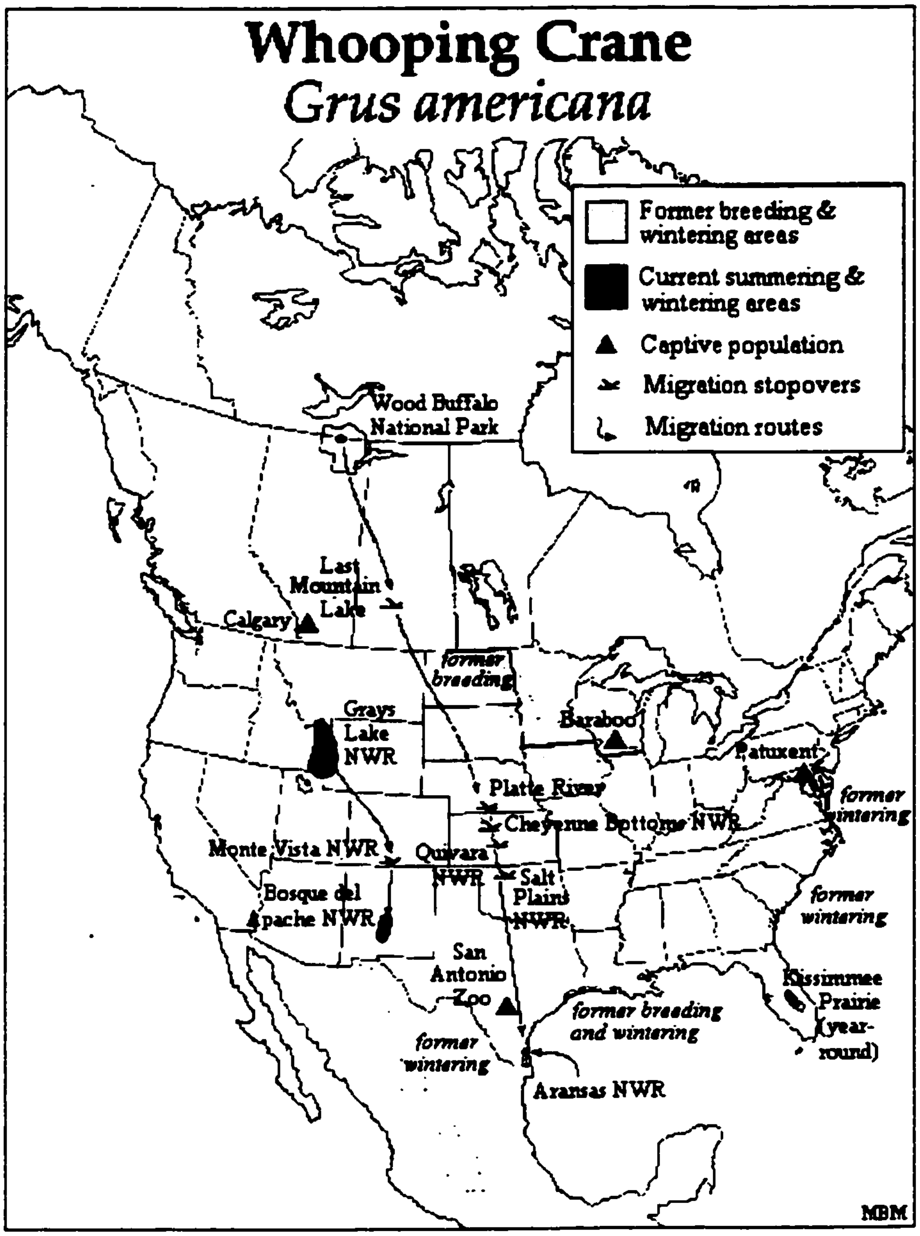


Figure 2.1: Whooping Crane Distribution

(from Meine and Archibald 1996)

2.4.2.2 Captive Populations

A number of Whooping Cranes have been retained in captivity with the hope that their offspring can be released into the wild to begin new migratory and non-migratory wild flocks in the future. The offspring of these captive-bred birds were used in the experimental releases in the U. S. Rocky Mountains in the 1970s and 1980s; currently they are being released onto the Kissimmee Prairie in Florida.

The majority of captive Whooping Cranes are held in three major North American captive breeding facilities: the Devonian Wildlife Conservation Centre of the Calgary Zoo in Calgary, Alberta, the International Crane Foundation in Baraboo, Wisconsin, and the United States Government Fish and Wildlife Service Patuxent Wildlife Research Centre in Laurel, Maryland. There are also several pairs in smaller captive breeding programs at the Freeport McMoRan Audubon Species Survival Center in New Orleans, Louisiana, and the San Antonio Zoo.

2.5 Population Size and Trends

2.5.1 Alberta

Historically, Whooping Cranes have existed at low numbers. It is believed that prior to 1870, when anthropogenic activities began to threaten habitat and populations, a maximum of only 1300 to 1400 individuals existed, in central North America and into the region of north-central Alberta (Allen 1952, Doughty 1989, Kuyt 1996). In 1941, Whooping Cranes reached an overall population low of only 15 remaining birds wintering in Texas and breeding in Wood Buffalo National Park (Meine and Archibald 1996). Currently, the number of birds that migrate to Wood Buffalo National Park each year is approaching 200 (Figure 2.2), with approximately six pairs nesting in Alberta in 1999 (B. Johns pers. comm.).

There exist no specific records as to the number of Whooping Cranes that bred in the province of Alberta prior to 1977. Between 1977 and 1987, only one pair was observed to nest within the Alberta border (B. Johns pers. comm.). Since 1988, the number of pairs observed nesting in

Alberta has fluctuated between one (in 1989 and 1991) and nine (in 1998) (Johns 1998a, B. Johns pers. comm.)

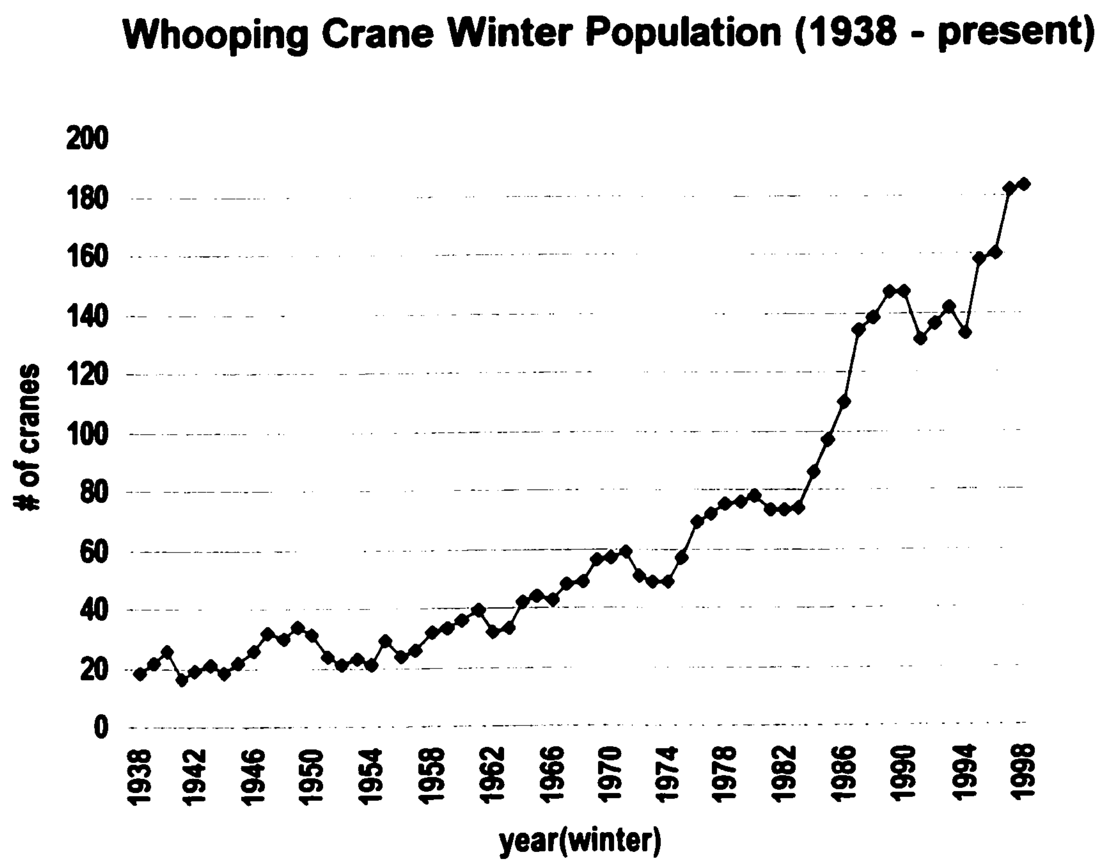


Figure 2.2: Whooping Crane Population Changes of the WBNP Migratory Flock (from Meine and Archibald 1996 with additional data from T. Stehn pers. comm.)

2.5.2 Other Areas

2.5.2.1 Wild Populations

Conservation efforts began in the early 20th century, when the dwindling populations were first documented (Edwards et al. 1994). By 1941, only 21 individuals remained: 15 individuals in a migratory flock and 6 individuals in a non-migratory flock (Meine and Archibald 1996). The non-migratory flock died out in Louisiana in 1949 (Edwards et al. 1994).

As of November 1, 1999, there were 254 wild Whooping Cranes (T. Stehn pers. comm.). Of these birds, 183 belong to the migratory Wood Buffalo –Aransas flock, 3 remain in the Rocky Mountains as a result of the cross-fostering experiments of the 1970s and 1980s, and 68 remain from releases in Florida (T. Stehn pers. comm., B. Johns pers. comm.).

Although the population increase is slow, and the species is still extremely vulnerable, the use of computer modelling predicted that the Wood Buffalo – Aransas population is large enough to sustain "fairly steady, though not invariant growth" and determined that the population can be expected to reach 500 individuals in approximately 27 years (Mirande et al. 1991). The Captive Breeding Specialist Group has projected that the Whooping Crane population faces a very low probability of extinction in the next 100years (Mirande et al. 1991).

2.5.2.2 Captive Populations

As of November 3, 1999, there were 139 Whooping Cranes in captivity at 5 captive breeding facilities in North America. The majority of Whooping Cranes are concentrated in three major breeding facilities: Patuxent Wildlife Research Centre in Maryland has 70 birds (44 adults, 26 young), the International Crane Foundation in Wisconsin has 36 birds (29 adults, 7 young), and the Calgary Zoo has 23 birds (21 adults, 2 young) (T. Stehn pers. comm.). The remaining birds are at the White Oak Conservation Center in Florida (1 adult), the Lowry Park Zoo in Florida (1 adult), the San Antonio Zoo (4 adults, 2 young), and the Audubon Institute in New Orleans (2 adults).

2.6 *Limiting Factors*

2.6.1 *Natural Limiting Factors*

There are a number of genetic and demographic threats directly associated with a species with an extremely small population size, including a decreased resistance to disease, skewed age distributions and sex ratios, and a vulnerability to stochastic occurrences such as storms, disease outbreaks, or other catastrophic events (Meine and Archibald 1996). Both wild and captive cranes are susceptible to a w ide variety of infectious or parasitic disease, including salmonellosis, avian tuberculosis, avian cholera, inclusion body disease of cranes (IBDC), crane herpes virus, eastern equine encephalitis, coccidiosis, avian pox, and Newcastle's disease (Carpenter and Derrickson 1987). It is especially important to monitor the offspring from captive flocks to ensure that diseases in captive cranes are not released into wild populations (Meine and Archibald 1996).

Another important consideration when considering threats to the Whooping Crane population is competition for food and resources among individuals as the slowly increasing population reaches carrying capacity, particularly in the wintering range (Gollop 1978). This can have far-reaching implications. During the winter of 1993-1994, the blue crab populations were exceptionally low on the wintering grounds, and as a result the following spring migration was erratic and 16 pairs failed to nest the next sum mer (Johns 1998a).

Abiotic factors can play a significant role in the short- or long-term fate of cranes, especially when considering the potential effects of stochastic events on small or highly concentrated populations (Meine and Archibald 1996). Weather events such as storms can cause extensive mortality to crane populations or can lead to setbacks in migration by physically blowing the Whooping Cranes hundreds of kilometres off course (Merrill 1961). F or example, a severe storm with hurricane force winds blew through the Canadian prairies and American midwest during the fall migration of 1998, and is suspected to be responsible for the deaths of several adult individuals (B. Johns pers. comm.).

Climate change can affect crane populations as well. Periods of drought can dry up critical wetland breeding areas and can also reduce food supplies and increase the vulnerability of chicks and nests to predation events (Kuyt et al. 1992). The threat of global warming and the predicted outcome on the environment has the potential to seriously compromise existing crane habitats (Meine and Archibald 1996).

2.6.2 Habitat Loss and Degradation

Habitat loss and degradation is one of the major threats to Whooping Crane survival and should be of primary concern to crane managers. Although both the breeding and wintering areas of the migratory flock are in protected areas, the 4500km migratory path that cranes fly twice a year is not subject to the same protection. Therefore, Whooping Cranes face their greatest threats to habitat loss and degradation during their southward and northward migrations.

Decline in habitat availability or quality can ultimately affect the distribution, movement, and breeding success of cranes (Meine and Archibald 1996). Whooping Cranes are potentially affected by loss and degradation of the North American landscape in their breeding grounds, migration resting points and staging areas, wintering grounds, resident habitats, and roosting areas.

Conversion of wetlands for development (be it agricultural, urban, commercial, or recreational), oil exploration, or road construction is the most significant threat affecting the overall vulnerability of cranes (Harris 1994). The process of converting wetlands reduced habitat suitability and availability, usually involving the clearing of naturally occurring vegetation, draining or altering of hydrologic processes, and burning, cultivation, or other activities, all of which may render habitat unsuitable for nesting, feeding, roosting, or stopping during migration (Meine and Archibald 1996). Conversion of grasslands to agricultural land has also had a similar effect (Allen 1952).

It is possible for cranes and humans to successfully coexist, but in some wetland areas the increasing human population growth and economic constraints have caused ecosystems and the resources they provide to be overtaxed (Meine and Archibald 1996). Human over-exploitation of the plant, animal (particularly fish), and water resources can have a negative impact on cranes as well as other species within the ecosystem, and can ultimately result in the cranes leaving the area seeking more suitable habitat (Doughty 1989).

The construction of dams and irrigation systems can irreparably alter the hydrologic regime of a landscape, and subsequently affect the stream channels and associated wetlands of river systems that can provide critical crane habitat (Meine and Archibald 1996). For example, dams in the northern stretches of the Platte River in Nebraska have altered the natural flood cycle of the area, allowing woody vegetation to take hold in what was once open riparian zones, reducing the availability of prime roosting sites for Whooping Cranes along their migratory route (Currier 1991).

Urban expansion and land development is a critical issue affecting Whooping Crane habitat. Development of wetlands and other crane habitat for human habitation has restricted the range of the Whooping Crane (Allen 1952). The subdivision and development of land can lead to habitat fragmentation. Properties that were once extensive become subdivided and fields, pastures, meadows, and wetlands are subsequently reduced in size and often fenced, which is shown to cause an effective reduction on foraging range of Whooping Cranes (Meine and Archibald 1996).

A significant problem on the wintering grounds of the Whooping Cranes at the Aransas National Wildlife Refuge in Texas is the erosion of coastal marsh vegetation and shoreline soils caused by dredging of channels, and the wave action of boat and barge traffic (Halpern 1992). Consequently, this results in a significant loss of critical wintering habitat for the Whooping Cranes.

Pollution and environmental contamination has the potential to play a significant role in the decline of Whooping Crane populations. Chemicals, organic wastes, and other pollutants can degrade water quality and, subsequently, can affect crane physiology and reproductive success as well as affecting the quality and availability of crane food sources within their wetland habitats (Meine and Archibald 1996). The production and transportation of chemicals along coastlines and major rivers make wetlands in these areas exceptionally vulnerable to the potential for a catastrophic pollution event (Meine and Archibald 1996). The Gulf Intracoastal Waterway in Texas, near the Aransas National Wildlife Refuge, is subjected to barge traffic carrying benzene, xylene, and other toxic chemicals on a daily basis; even one small spill in this area could have a devastating outcome on the Whooping Crane wintering population, their habitat, and their food sources (Lewis et al. 1992, Lewis 1995).

Oil development, consisting of exploration, drilling, extraction, transport, and processing, presents a potentially threatening situation with respect to pollution of crane habitats. Oil development activities take place within the Aransas National Wildlife Refuge; however these activities are restricted to the summer months when the Whooping Cranes have migrated to their northern breeding grounds (Ramirez et al. 1993). It is important to realize, though, that an accident or spill at other times of the year could still have a long-term impact on the environmental habitat quality throughout the Aransas reserve (Meine and Archibald 1996). Continuous low level discharge of pollutants related to the production and transportation of oil can also be of concern to the overall well being of Whooping Cranes (Lewis 1995, Robertson et al. 1992).

The accidental collision with power lines during flight can be a source of mortality for Whooping Cranes (Brown et al. 1987, Faanes and Johnson 1992, Howard et al. 1987). Relocating, removing, burying, or marking the utility lines can mitigate this threat, although it is an expensive and time-extensive task (Meine and Archibald 1996). Collision with other infrastructure on the landscape, such as fences, can also result in accidental injury or even death in Whooping Cranes (Allen and Ramirez 1990).

2.6.3 Hunting

Overhunting is one of the threats that led the Whooping Crane to its current endangered status. Because of a lack of enforced hunting restrictions in the 19th and early 20th century, it is impossible to know exactly how many of the once abundant Whooping Cranes were hunted for sport and for food (Doughty 1989). Today there are strict hunting regulations enforced in both Canada and the United States, however accidental shooting due to misidentification and poaching along the migratory pathway can still be of concern (Doughty 1989).

2.7 Status Designations

2.7.1 Alberta

Whooping Cranes are a 'Red-Listed' species in Alberta (Alberta Wildlife Management Division 1996). The red-list is reserved for species that are currently at risk of extirpation or extinction, whose populations have either declined to nonviable levels or show a rate of decrease that indicates an immediate risk of declining to nonviable levels (Alberta Wildlife Management Division 1996). The species is also designated legislatively as an 'endangered' animal under the provincial wildlife act.

2.7.2 Other Areas

By the time awareness of the dwindling Whooping Crane population reached government, the species was in grave danger of extinction. To ensure the species had a chance of surviving, it was necessary to protect their critical breeding and wintering habitat and cease hunting. In 1916, the Migratory Birds Convention Act was passed which allowed for the outright ban of hunting of Whooping Cranes (Gollop 1978, RENEW 1998).

COSEWIC (the Committee on the Status of Endangered Wildlife in Canada) listed the Whooping Crane as 'endangered' in 1978, the first year that such designations were made (RENEW 1998). The Whooping Crane remains on the COSEWIC list of endangered species today. The United States formally declared the Whooping Crane to be endangered several years earlier, in 1967 (RENEW 1998). The International Union for the Conservation of Nature and Natural Resources (IUCN), an organization that encompasses many of the world's conservation agencies, governmental, and non-governmental institutions, classified the Whooping Crane as endangered in 1996.

2.8 *Recent Management in Alberta*

In 1937, the Aransas National Wildlife Refuge was established in Texas to protect the wintering grounds of the Whooping Crane (Doughty 1989). A search began to discover the northern breeding grounds and in 1954, after ten years of extensive searching, they were finally discovered (Allen 1956, Doughty 1989, McCoy 1996). The Whooping Crane's breeding grounds were within the boundaries of Canada's Wood Buffalo National Park, a parcel of land that has been protected since 1922.

The increase in the wild population of Whooping Cranes is attributable to many interacting factors, including an intensified public awareness campaign to reduce accidental shooting, the legal protection of the species and its critical breeding and wintering habitat, and captive breeding programs.

While there are no Whooping Crane management initiatives underway currently by the province of Alberta, there are a number of federal (Canadian and American) management programs in effect.

In 1988, Canada adopted a national recovery plan for the species, which consisted of a number of goals and specific objectives for the conservation of Whooping Cranes (Edwards et al. 1994). The primary objectives of the recovery plan were to establish a stable or increasing Wood Buffalo-Aransas migrating population with a minimum of 40 breeding adult pairs for 10 consecutive years (an objective which has been consistently attained from 1995 to the present) and to establish and support two additional wild Whooping Crane populations, each with a minimum of 25 breeding adult pairs by the year 2020 (Edwards et al. 1994). Only when these population objectives have been maintained for 10 consecutive years, will the objectives be considered to have been successfully achieved (Edwards et al. 1994). Once this has occurred, there will remain further recovery efforts required to eventually remove the Whooping Crane from the COSEWIC list (Edwards et al. 1994).

The Canadian Wildlife Service regularly surveys the breeding grounds throughout the summer months to monitor the cranes' breeding population and productivity (Gollop 1978). On the wintering grounds, it is the responsibility of the US Fish and Wildlife Service to monitor the Whooping Crane population (Gollop 1978). A "Memorandum of Understanding" exists between the Canadian Wildlife Service and the US Fish and Wildlife Service, which officially documents the co-operative effort required in the management of the Whooping Crane, an internationally migratory species (Edwards et al. 1994). This memorandum serves to improve co-ordination and co-operation in Whooping Crane management, research, and conservation (Edwards et al. 1994). This agreement is essential to improve the quality of crane habitat and survival, to enhance and maximize management programs in both countries while avoiding duplication of effort, to improve existing practices for exchanging information, individual birds, and eggs, and to allow for the creation of new flocks and wild populations (Edwards et al. 1994).

Whooping Crane management in North America is focused on two separate and distinct areas: management of the wild and migrating crane populations, and management of cranes in captive breeding programs. It is important that both of these distinct managerial issues be considered together. Without the capture of wild adults or the removal of eggs from nests in the wild, it would be impossible to have the three captive populations that exist today. Conversely, without the captive-bred animals, the establishment of additional wild populations would be impossible. Captive-bred birds released into new wild populations can help counteract population losses from biological processes including predation, disease, and death from environmental catastrophes such as storms, and from anthropogenic interference.

Academics, corporate sponsors, governmental agencies, and environmental non-governmental organizations have worked together to provide the funding and research required to gain the level of understanding about the species that we have today. Whooping Crane research received an allocation of $120,000 in 1997-1998 by government agencies, non-governmental organizations, universities, and corporate and private donors (RENEW 1998).

2.9 *Synthesis*

The most critical issue in the management of Whooping Cranes is their low population size, which is currently over 200 individuals in the wild. This represents an extremely vulnerable population, with a number of anthropogenic, biological, and environmental factors threatening the stability and overall viability of the species. To manage the species successfully, we must first mitigate anthropogenic threats to Whooping Cranes, including continued habitat loss and degradation, wetland conversion, over-exploitation of wetland resources, agricultural conversion of grasslands, creation of dams and water diversions, land development and urban expansion, coastal marsh and shoreline erosion, pollution and contamination, and oil exploration and development (Meine and Archibald 1996). In addition to mitigating these threats, it is still critical to bring the wild population to a sufficient size and to establish more than one biologically self-sustaining and therefore viable wild population in order to allow for population losses as a result of non-mitigable threats such as biological or environmental catastrophes.

Miraculously, Whooping Cranes have survived as a species, despite reaching a population low of only fifteen individuals almost sixty years ago. The Canadian national recovery plan for the Whooping Crane deals with breeding and migratory issues, and the American national recovery plan covers wintering and migratory issues. The Canadian Wildlife Service and the U.S. Government Fish and Wildlife Service completed a memorandum of understanding that combines the separate goals and objectives of both recovery plans into related goals and objectives related to the establishment of additional wild populations.

The Whooping Crane, having come so close to extinction, is a species particularly in need of management to maximize genetic diversity because the founding gene pool of the existing birds was so limited. A lack of diversity within a species can lead to a reduced disease resistance, a decrease in overall fertility, and an increase in mortality of embryos (Mirande et al. 1996a, 1996b). It is important to continue co-ordinating captive management efforts to preserve genetic diversity among Whooping Cranes, for it is the chicks reared from captive flocks that are used to supplement the wild populations (Mirande et al. 1996b). It is hopeful that these practices will lead one day to a number of self-sustaining wild populations and that captive breeding will no longer be required. Efforts should continue to be made at all times to pair individuals together whose offspring will have low inbreeding coefficients and therefore maximize the genetic diversity of the species (Mirande et al. 1996b).

In order to have a continued population increase, it is necessary to devote research time and financial support to the minimization and mitigation of anthropogenic threats to the species. It is also important to be able to enact the existing contingency plans in the instance of non-mitigable environmental and biological threats. With careful management of both the wild and captive populations of Whooping Cranes, and with wildlife managers dedicated to attaining the goals and objectives outlined within the recovery plans, we can be hopeful that the species will continue to increase. For the time being, we can be confident that the Whooping Crane is an endangered

species that is well-managed: it is this management that is allowing recovery from near-extinction in the early 20^{th} century.

3.0 Behaviour of Whooping Cranes at the Devonian Wildlife Conservation Centre

"When we hear his call we hear no mere bird. We hear the trumpet in the orchestra of evolution."

Aldo Leopold, 1949

3.1 *Introduction to the DWCC Behaviour Study*

In 1989, Calgary was chosen by the Whooping Crane Recovery team and the Canadian Wildlife Service to serve as the Canadian captive-breeding centre for Whooping Cranes. DWCC staff was sent to ICF in 1991 for training in all aspects of husbandry and management of Whooping Cranes. The Nat Christie Foundation provided funding to build the facility, including the breeding pens and buildings for chick-rearing and incubation. The goal of the DWCC captive breeding program is to have 10 successful breeding pairs. The major obstacles to reaching this goal are the same as those faced by all captive-breeding facilities: Whooping Cranes in captivity breed unpredictably (if at all) and their breeding behaviour and success is dependent on a strong, difficult to manage, and incompletely understood pair-bond. One key to improving the breeding success of captive cranes is to understand the behaviour of each individual and pair.

Increasing our understanding of behaviour in captive Whooping Cranes may offer clues to improving success in the future. This has been shown to be effective in the captive breeding of other species. Peregrine Falcons bred unpredictably in captivity for years until an improved understanding of the effects of their life history their behaviour and the on breeding success were discerned (Cade and Fyfe 1977, Cade 1990, Weaver and Cade 1991). This caused a great improvement in the success of Falcon captive breeding programs (Cade and Fyfe 1977, Cade 1990, Weaver and Cade 1991).

The evaluation of the behaviour of the Whooping Cranes at the Devonian Wildlife Conservation Centre was one of the five major objectives for this Master's Degree Project. Behaviour was studied to provide an understanding of this complex aspect of the life history of this species and to generate insights into possible causes of poor reproductive success. This chapter presents the methodology used to evaluate the behaviour, the results found, and discusses the relevance of these results to the overall purpose of this Master's Degree Project.

3.2 *Methods*

I undertook a study of the ethology of captive cranes during the 1999 breeding season at the Devonian Wildlife Conservation Centre, located immediately south of the city of Calgary in the municipality of Foothills, east of the community of Dewinton. Ethology, defined as the application of established scientific and biological methods to the problems of behaviour, is not only a study of what an animal does, but also includes when, how, why, and where the behaviours occur (Lehner 1979).

The major concern when conducting an observational study is determining the effect that the observer's presence has on the behaviour of the study subjects (Robson 1993). This effect can be minimized by either the study subjects becoming so accustomed to the observer's presence that they behave as though she is not there, or by ensuring that the observed are unaware that they are being observed (Robson 1993). I used a blind to allow direct observation of the birds while minimizing any potential effect my presence may have on the cranes (Lehner 1979). Every effort was made to ensure that Whooping Cranes under observation were unaware of the presence of observers, all of whom remained out of sight, sound, and scent in observational blinds during the monitoring sessions. The observational blinds were placed near the crane's enclosures prior to breeding season so that the birds would become accustomed to their presence as a part of their surrounding scenery. In one instance, topography prevented an observation blind from being placed a sufficient distance from the crane enclosure, and so observations were made on videotape from a camera mounted within the cranes' enclosure. Because birds could be out of the observers' sight as a result of entering their buildings or as a result of sight lines from the observation blind, when behaviour could not be recorded, the cranes were indicated to be 'out of sight.' All comparisons were made using the proportion of time that the birds were in sight, and therefore the denominators varied among individuals.

Each pair was observed for twenty sessions, two-hours in duration, beginning one-half hour prior to sunrise and continuing for one and one-half hours following sunrise every other day for six weeks during the peak of their breeding season (late March to early May). Focal pair instantaneous sampling was combined with all occurrences sampling of courtship behaviours, using a nominal scale of measurement for recording. These methods were chosen because the focal animal method of behavioural research sampling is preferable in protocols where the specific individual that performs the behaviour is of interest, and instantaneous sampling is an effective methodology when it is the behaviour performed is of interest (Lehner 1979, Lehner 1992).

The frequency of breeding behaviour events (dancing and breeding behaviour sequences) was recorded using all occurrences sampling and the focal pair method (Lehner 1979). In addition, the activity of individuals and pairs was recorded at five-minute intervals during the same two-hour observation sessions to define and compare activity budgets for each pair. Focal pair sampling is when behaviour exhibited by a specific mated pair of animals is recorded during any sample period (Lehner 1979, Lehner 1992). This is particularly useful when there are too many discrete behaviours or the behaviours occur too rapidly to accurately record data from many individuals (Lehner 1992). Instantaneous sampling is used when the behaviour exhibited at predetermined points in time is recorded (Lehner 1992). All occurrences sampling is a type of sampling strategy where the focus is on a limited number of behaviours that are carefully defined, easily recognized, and do not occur more rapidly than the observer can record (Lehner 1979). Each observation was recorded using a nominal scale of measurement to determine the frequencies of behaviours that differed qualitatively (Lehner 1979, Lehner 1992).

Observational biases, including selective attention, selective encoding, and selective memory (Robson 1993), were minimized through the use of timed schedules for recording behavioural observations. When describing a crane's behaviour, functional descriptions, or description of the behaviour in reference to its proximal or ultimate function (Lehner 1979), were used at all times. Sampling was conducted during a period of two hours surrounding sunrise each day, the time when cranes are believed to exhibit most of their breeding behaviours (D. Knapik pers. comm.)

The mating behaviour, sequences, and patterns of cranes are specific to each species (Masatomi 1983). An ethogram is a comprehensive description of a set of behavioural patterns of a species (Lehner 1979). Ethograms for the Whooping Crane and other crane species have been described (Ellis et al. 1998, Ellis et al. 1991, Nesbitt and Archibald 1981, Poulson 1975). Whooping Cranes exhibit a total of 83 discrete behaviours consisting of:

- 6 vocalizations,
- 20 agonistic displays,
- 6 attack and mob behaviours,
- 6 defensive and submissive displays and actions,
- 5 types of concordant behaviour,
- 6 types of pair-related behaviour,
- 4 behaviours associated with nest preparation and maintenance,

- 13 types of parental behaviour, and
- 7 types of filial behaviour (Ellis et al. 1998).

These were appended to a list of 41 behaviours (described in appendix 7.1) that was used for recording behavioural observations at DWCC. Whooping Cranes exhibit a fixed repertoire of behaviours during a breeding courtship (Ellis et al. 1998). There are six stages of behaviour leading to successful copulation, each of which has a defined possible termination stage. Dancing may precede this breeding behavioural sequence. Descriptions of breeding behaviour were recorded using a scale from 1 to 8, where 8 denotes complete copulation (Figure 3.1). All occurrences of dancing behaviour were recorded. An illustration of each stage of the breeding behaviour sequence scored and categorized is shown below (Figure 3.2).

Figure 3.1: Whooping Crane Breeding Behaviour Sequence

Stage 1:	pre-copulatory call and march	terminated by either male or female ceasing marching	Incomplete Copulation
Stage 2:	wing solicitation by male or female	terminated by either male or female ceasing solicitation as other approaches	
Stage 3:	female solicits and holds	terminated by male not attempting to mount	
Stage 4:	male attempts to mount female	terminated by male failing to mount	
Stage 5:	male mounts female	terminated by male failing to hold on female's back and going over her head	
Stage 6:	male holds on female's back	terminated by lack of cloacal contact between male and female	
Stage 7:	SUCCESSFUL COPULATION		

Breeding Behaviour Sequence Score:

1 = Parading / marching

2 = Solicitation by male or female

3 = Female solicits but will not hold as male approaches

4 = Female solicits and holds but male will not attempt to mount

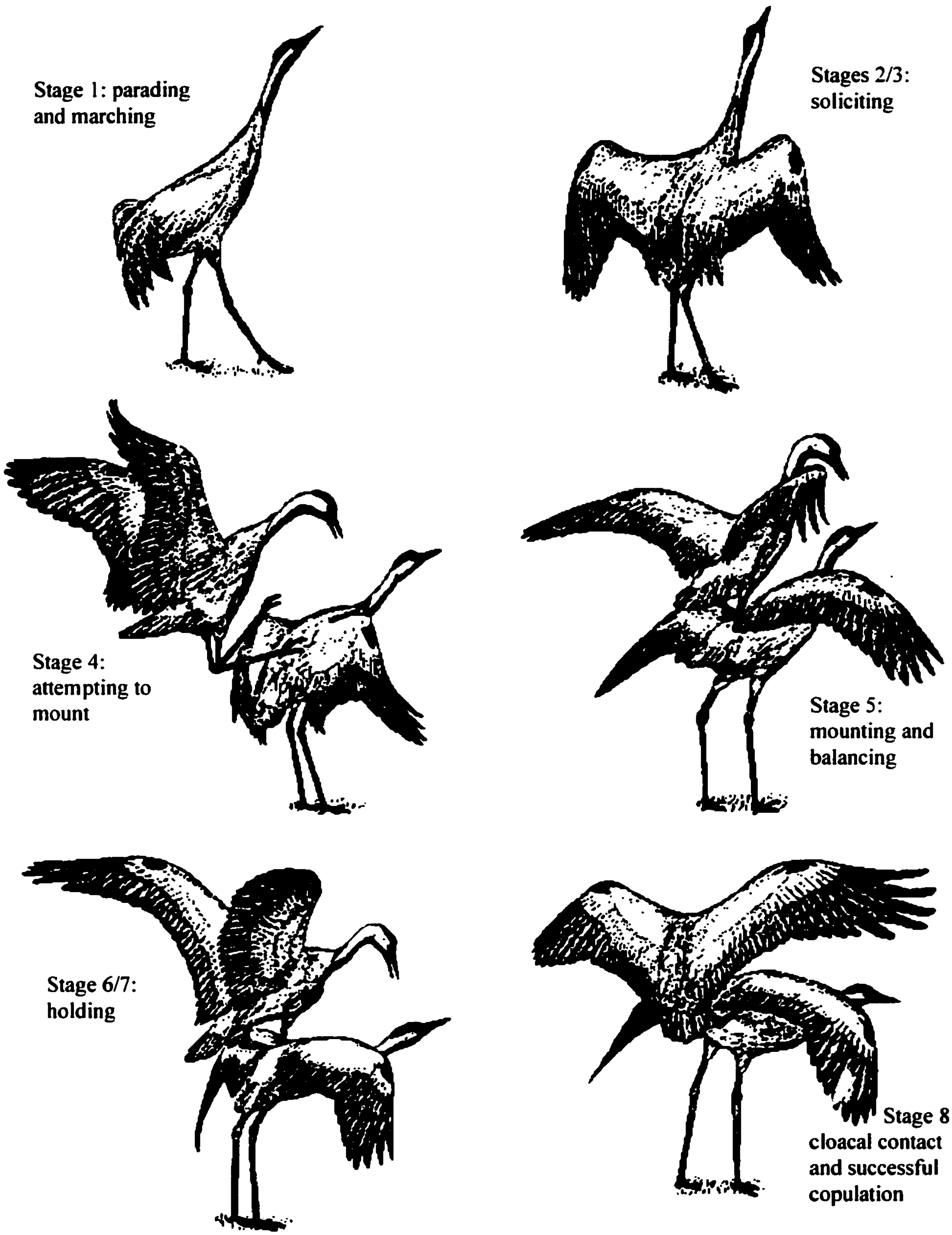
5 = Male attempts to mount female but fails to jump properly

6 = Male jumps on female but goes over the female's head

7 = Male holds on female's back but no cloacal contact occurs

8 = Male holds on female's back and cloacal contact occurs

Figure 3.2: Illustrated Whooping Crane Breeding Behaviour Sequence



Pictured above: Eurasian Crane (Grus grus) (from Walkinshaw 1973)

In addition to the behavioural study conducted during the 1999 breeding season, I accessed past breeding records for the DWCC Whooping Cranes from 1992 to 1998 and conducted key informant interviews with the facility manager to obtain information about past breeding occurrences.

3.3 Results

The Devonian Wildlife Conservation Centre officially became a part of the Whooping Crane captive-breeding program in November 1992 when they received their first pair of Whooping Cranes, 'Duncan' (male), and 'Wisconsin' (female). In the early spring of 1993, about three months later, they received one more pair: 'Borden' (who was thought to be a male, but determined to be female several years later) and 'Lizzie' (female). They continued to receive one or two pairs at a time over the next few years, with the majority arriving in 1993 and 1994 (D. Knapik pers. comm.). At the start of the 1999 breeding season there were nine pairs involved in the captive-breeding program. In 1994, the DWCC staff isolation-reared their first chick, which was hatched from a wild egg collected in Wood Buffalo National Park.

Prior to 1999, only one pair had successfully reproduced ('Hope' [male], and 'Chinook' [female]). In 1995, 'Hope' and 'Chinook' laid four eggs, which were all infertile (D. Knapik pers. comm.). They were given a Sandhill Crane chick to raise. 'Chinook' was at the time the youngest female Whooping Crane to ever lay an egg in captivity (at 4 years and 14 days). This record has since been improved by a Whooping Crane at ICF. In 1996, 'Hope' and 'Chinook' laid five eggs, which were all fertile (D. Knapik pers. comm.). Of these, three were reared to fledging and were released in Florida, where they all died within a month of release. 'Hope' and 'Chinook' were given a Whooping Crane chick to rear for practice.

In 1997, 'Hope' and 'Chinook' laid six eggs, of which one was fertile. 'Hope' and 'Chinook' attempted to rear this chick, however it died at five days, as a result of unseasonably cold temperatures (D. Knapik pers. comm.). 'Hope' and 'Chinook' laid seven eggs in 1998, of which two were fertile (D. Knapik pers. comm.). Both of these chicks were isolation-reared and released in Florida in mid-February 1999. 'Hope' and 'Chinook' were given a chick from an abandoned nest in WBNP to raise, which was slated for release but sustained an injury to her wing and now remains in captivity at the DWCC.

In 1995, egg contents were found in the water bucket of the enclosure of 'Nat' (male) and 'Christie' (female), although no shell was ever found and nothing has been observed since (D. Knapik pers. comm.). In 1997 'L'esperance' (male) and 'Susan' (female) laid four eggs, of which two were found broken and two were removed from the nest before they could be broken, but were infertile (D. Knapik pers. comm.). The pattern continued in 1998 when 'L'esperance' and 'Susan' laid and broke three eggs (D. Knapik pers. comm.).

Nine mated pairs or eighteen individuals were a part of the 1999 behavioural observation study at the DWCC. The DWCC Whooping Cranes observed were all at the age of sexual maturity, varying in age from 4 to 11 (Table 3.1). The method of rearing varied for each pair of Whooping Cranes: some individuals were raised by a puppet-rearing method, others by Whooping Crane parents, by costumed keepers, by hand, or by Sandhill Crane surrogate parents (Table 3.1). Attempts were made to observe each pair for 20 observation sessions; studied every other day for a period of 6 weeks encompassing the breeding season. Only seven of the 9 pairs were observed for the full twenty sessions (Table 3.2).

All pairs were observed dancing on at least one occasion, and as many as eleven different days of observation (Table 3.3). All pairs were observed to participate in at least one copulation attempt, although for two pairs it was only one attempt that ranked a score of '1' (the lowest possible score) (Table 3.3). Successful copulation, receiving a score of 8, was observed four times in one pair ('Hope' and 'Chinook', but was not observed in any of the other pairs.

The 1999 breeding season at the DWCC was record setting, in that there were three pairs that laid a total of 13 eggs. 'Hope' and 'Chinook' laid eight eggs, 'Antony' and 'Lizzie' laid four eggs, and 'Cal' and 'Nelson' laid one egg (Table 3.4). Only two eggs were fertile and resulted in the hatching of a chick, while the other 11 were either infertile, broken, or were fertile but the chick died before hatching (Table 3.4). Records at the DWCC reveal that successful copulation has been observed only 7 times in the past four years, always by one pair (Hope and Chinook) (Table 3.6). Similar to 1999, in previous years other pairs were observed displaying some breeding behaviour.

Not all Whooping Cranes were expected to breed successfully in 1999 (Table 3.5). In two pairs, the males had sustained injuries that could prevent successful mounting and balancing during copulation, two pairs were recently re-paired in the fall of 1998, and two pairs (including one of the newly established pair bonds) were separated during the breeding season as a result of male aggression.

Whooping Cranes at the DWCC were observed to successfully copulate on overcast, clear, or partly cloudy days ranging from April 7 to May 18, between 6:10 and 9:00AM, when the outside temperature was between –7 and +7° Celsius, when it was calm or windy (Table 3.7). It is important to keep in mind that these observations do not necessarily represent all successful copulation events that took place, only those that were observed.

Table 3.1: Age and Rearing Method of DWCC Whooping Crane Pairs

Male	Age (years)	Rearing Method	Female	Age (years)	Rearing Method
'Hope'	7	Costume	'Chinook'	8	Parent (Whoopers)
'Antony'	6	Costume	'Lizzie'	10	Parent (Sandhills)
'Cal'	7	Costume	'Nelson'	6	Costume
'Duncan'	10	Costume	'Aurora'	6	Costume
'Lancelot'	6	Parent (Whoopers)	'Gwenivere'	7	Costume
'Nat'	7	Costume	'Christie'	7	Costume
'Spree'	4	Costume	'Cleopatra'	6	Parent (Whoopers)
'Ish'	6	Hand	'Eha'	7	Costume
'L'esperance'	7	Costume	'Susan'	11	Parent (Sandhills)

** note, shading denotes pairs that laid an egg(s) in 1999*

Table 3.2: Field Observation Days

Male	Female	# Days Observed	Reason (if observed less than 20 days)
'Hope'	'Chinook'	20	-
'Antony'	'Lizzie'	20	-
'Cal'	'Nelson'	20	-
'Duncan'	'Aurora'	20	-
'Lancelot'	'Gwenivere'	20	-
'Nat'	'Christie'	20	-
'Spree'	'Cleopatra'	20	-
'Ish'	'Eha'	7	Separated April 12/99 because of male aggression
'L'esperance'	'Susan'	11	Separated April 25/99 because of male aggression

* *note, shading denotes pairs that laid an egg(s) in 1999*

Table 3.3: Breeding Behaviour of DWCC Whooping Cranes, 1999

Male	Female	Dancing Observed?	Copulation attempts?	Copulatory Scoring Details[α]
'Hope'	'Chinook'	yes, 1 day	yes, 5 attempts	8, 8, 8, 2, 8
'Antony'	'Lizzie'	yes, 1 day	yes, 14 attempts	4, 5, 4, 3, 3, 5, 3, 4, 4, 7, 1, 6, 6, 7
'Cal'	'Nelson'	Yes, 10 days	yes, 7 attempts	6, 3, 3, 6, 5, 1, 1
'Duncan'	'Aurora'	Yes, 11 days	yes, 3 attempts	1, 1, 3
'Lancelot'	'Gwenivere'	yes, 7 days	yes, 10 attempts	1, 6, 1, 4, 1, 5, 6, 4, 3, 6
'Nat'	'Christie'	yes, 3 days	yes, 1 attempt	1
'Spree'	'Cleopatra'	yes, 4 days	yes, 3 attempts	1, 4, 3
'Ish'	'Eha'	yes, 2 days	yes, 1 attempt	1
'L'esperance'	'Susan'	yes, 3 days	yes, 5 attempts	1, 1, 3, 3, 1

α
1 = Parading / marching

2 = Solicitation by male or female

3 = Female solicits but will not hold as male approaches

4 = Female solicits and holds but male will not attempt to mount

5 = Male attempts to mount female but fails to jump properly

6 = Male jumps on female but goes over the female's head

7 = Male holds on female's back but no cloacal contact occurs

8 = Male holds on female's back and cloacal contact occurs

** note, shading denotes pairs that laid an egg(s) in 1999*

Table 3.4: Egg Laying of DWCC Whooping Crane Pairs

Male	Female	# of eggs laid in 1999	Outcome
'Hope'	'Chinook'	8	3 – infertile 2 – fertile and hatch 2 – fertile and die before hatching 1 – fertile and broken by parents
'Antony'	'Lizzie'	4	3 – infertile 1 – fertile and dies before hatching
'Cal'	'Nelson'	1	1 – unknown fertility and broken by parents
'Duncan'	'Aurora'	-	
'Lancelot'	'Gwenivere'	-	
'Nat'	'Christie'	-	
'Spree'	'Cleopatra'	-	
'Ish'	'Eha'	-	
'L'esperance'	'Susan'	-	

* *note, shading denotes pairs that laid an egg(s) in 1999*

Table 3.5: Barriers to Successful Breeding in DWCC Whooping Cranes

Male	Female	Potential barriers to successful copulation in 1999?
'Hope'	'Chinook'	-
'Antony'	'Lizzie'	-
'Cal'	'Nelson'	-
'Duncan'	'Aurora'	-
'Lancelot'	'Gwenivere'	First breeding season together
'Nat'	'Christie'	male had an injured toe that could prevent mounting during copulation
'Spree'	'Cleopatra'	male has a fixed wing that could prevent balancing during copulation
'Ish'	'Eha'	first breeding season together, separated April 12/99
'L'esperance'	'Susan'	separated April 25/99

** note, shading denotes pairs that laid an egg(s) in 1999*

Table 3.6: Breeding Behaviour of DWCC Whooping Cranes, 1995-1997

Year	Male (age)	Female (age)	# of days observed	Copulation attempts?	Copulatory Scoring Details[α]
1995	'Hope' (3)	'Chinook' (4)	57	yes, 19 attempts	1, 1, 2, 7, 1, 1, 1, 1, 1, 1, 1, 2, 7, 7, 7, 2, 8, 8, 8
	'Borden'(5)[β]	'Lizzie' (6)	40	yes. 10 attempts	1, 1, 1, 1, 1, 1, 1, 1, 1, 1
	'Duncan' (6)	'Wisconsin' (4)	40	yes. 8 attempts	1, 1, 1, 2, 1, 1, 1, 2
1996	'Hope' (4)	'Chinook' (5)	53	yes, 11 attempts	1, 6, 1, 1, 1, 1, 1,8, 1, 8, 1
	'Borden' (6)[β]	'Lizzie' (7)	40	yes, 9 attempts	1, 1, 1, 1, 1, 1, 2, 1. 1
	'Duncan' (7)	'Wisconsin' (5)	40	yes, 5 attempts	2, 1, 1, 1, 2
1997	'Hope' (5)	'Chinook' (6)	29	yes, 8 attempts	6, 1, 8, 1, 1, 2, 1, 8
	'Cal' (5)	'Nelson' (4)	29	yes, 7 attempts	1, 1, 2, 2, 6, 3, 5
	'Lancelot' (4)	'Eha' (5)	29	Yes, 1 attempt	1

* *note, shading denotes pairs that laid an egg(s) during that year*

α 1 = Parading / marching

2 = Solicitation by male or female

3 = Female solicits but will not hold as male approaches

4 = Female solicits and holds but male will not attempt to mount

5 = Male attempts to mount female but fails to jump properly

6 = Male jumps on female but goes over the female's head

7 = Male holds on female's back but no cloacal contact occurs

8 = Male holds on female's back and cloacal contact occurs

β *'Borden' was determined in 1997 to be female.*

Table 3.7: Weather Conditions when Successful Copulation was Observed, 1995-1999

Date Successful Copulation Observed	Time Observed	Temperature (° Celsius)	Weather
27-Apr-1999	6:40AM	0 to +4	cool, slightly overcast
13-Apr-1999	6:49AM	-1 to 0	overcast
7-Apr-1999	6:50AM	+4 to +5	warm, cloudy
30-Mar-1999	6:30AM	-7 to –2	cold, overcast
30-Apr-1997	6:55 – 8:00AM	+1	clear, cool
13-Apr-1997	7:00 – 9:00AM	-4	clear, cold
26-Apr-1996	6:10 – 8:00AM	-1	partly cloudy
22-Apr-1996	6:25 – 8:25AM	-6	clear, cold
18-May-1995	6:10 – 7:35AM	+7	overcast, calm
16-May-1995	6:20 – 8:40AM	+6.5	clear, windy
10-May-1995	6:20 – 8:20AM	-1	clear, cold

** note, 1999 observations were made by the author: 1995-1997 observations were made by DWCC staff and Calgary Zoo docent volunteers, and obtained from DWCC records*

Of the 41 behaviours and actions included on the crane observations checklist and data sheet (section 7.1), only 16 were recorded using instantaneous sampling. The behaviours observed were:

- standing,
- sleeping,
- preening,
- stretching or scratching,
- feather shaking,
- walking,
- digging and foraging,
- alert,
- run/dash,
- unison call,
- dancing,
- precopulatory calling,
- solicitation,
- nest building,
- incubating, and
- egg turning.

Without exception, all birds spent the highest percentage of time preening (Tables 3.8-3.16). The proportion of time devoted to this activity varied from 37.4% ('Chinook') to 74.8% ('Susan'). The second most common behaviour observed varied between individuals: standing in 6 males and 4 females, digging and foraging in 3 females, walking in 1 male and 1 female, and incubating in 2 males and 1 female (Tables 3.8-3.16).

No significant differences were found between the proportion of time spent by males and females in any of the behaviours (G-test, Williams' correction for continuity). The activity budgets of 'Hope' and 'Chinook', the most successful breeding pair during the 1995 through 1999 breeding seasons, were compared to the activity budgets of the other eight pairs using the same test statistic. There were no significant differences in activity budgets among pairs.

Males and females in each mated pair were found to have very few significant differences in percent of time in each behaviour or activity. Chi-squared tests revealed several significant differences in behaviour at the pair level. 'Nat' (male) slept significantly more than 'Christie' (female) ($p<0.05$) (Table 3.8). 'Eha' (female) was observed digging and foraging and sleeping significantly more than 'Ish' (male) ($p<0.05$), while 'Ish' walked significantly more than 'Eha' ($p<0.05$) (Table 3.9). 'Chinook' (female) slept and incubated significantly more than 'Hope' (male) ($p<0.05$), while 'Hope' was observed preening significantly more than 'Chinook' ($p<0.05$) (Table 3.10). 'Antony' (male) incubated significantly more and dug and foraged significantly less than 'Lizzie' (female) ($p<0.05$) (Table 3.11). 'Aurora' (female) was observed digging and foraging significantly more and precopulatory calling significantly less than 'Duncan' (male) ($p<0.05$) (Table 3.14). 'Gwenivere' (female) slept significantly more than 'Lancelot' (male) ($p<0.05$) (Table 3.15).

There were no significant differences in behaviour observed between the males and females of three pairs: 'Spree' (male) and 'Cleopatra' (female), 'Cal' (male) and 'Nelson' (female), and 'L'esperance' (male) and 'Susan' (female) (Tables 3.12, 3.13, and 3.16, respectively).

Table 3.8: Activity Budget for 'Nat' and 'Christie'

BEHAVIOUR	*'Nat' (male)*	*'Christie' (female)*	*'Nat' and 'Christie'*
Standing	10.4	7.7	8.9
Sleeping[δ]	6.2	2.7	4.5
Preening	71.8	71.9	71.8
Stretch/Scratch	0	0	0
Shake	0	0.4	0.2
Walking	6.6	6.6	6.6
Digging	4.2	10.2	7.2
Alert	0.4	0.4	0.4
Run/Dash	0	0	0
Unison Call	0	0	0
Dancing	0	0.4	0.2
Precopulatory Call	0.4	0	0.2
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*259*	*256*	*515*
Total # Days Observed	*20*	*20*	*20*

** note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.9: Activity Budget for 'Ish' and 'Eha'

BEHAVIOUR	*'Ish' (male)*	*'Eha' (female)*	*'Ish' and 'Eha'*
Standing	14.4	10.5	12.5
Sleeping$^{\delta}$	4.6	11.8	8.2
Preening	54.2	58.6	56.4
Stretch/Scratch	0	0	0
Shake	0	0	0
Walking$^{\delta}$	20.9	5.9	13.4
Digging$^{\delta}$	3.9	11.8	7.9
Alert	0.7	0.7	0.7
Run/Dash	0	0	0
Unison Call	0	0	0
Dancing	0	0	0
Precopulatory Call	1.3	0.7	1
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*153*	*152*	*305*
Total # Days Observed	*7*	*7*	*7*

* *note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.10: Activity Budget for 'Hope' and 'Chinook'

BEHAVIOUR	'Hope' (male)	'Chinook' (female)	'Hope' and 'Chinook'
Standing	11	8.3	9.7
Sleeping[δ]	0	5.8	2.8
Preening[δ]	54.1	37.4	46
Stretch/Scratch	0	0	0
Shake	0	0	0
Walking	9.8	11.8	10.8
Digging	5.7	8.5	7.1
Alert	0.2	0.3	0.2
Run/Dash	0	0	0
Unison Call	0.5	0.5	0.5
Dancing	0.7	0	0.4
Precopulatory Call	1	0.5	0.7
Solicitation	0	0.3	0.1
Nest Building	0.2	0.3	0.2
Incubating[δ]	16	25.9	20.8
Egg Turning	0.7	0.5	0.6
Total # Daily Obs. (In Sight)	*418*	*398*	*816*
Total # Days Observed	*20*	*20*	*20*

* *note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.11: Activity Budget for 'Antony' and 'Lizzie'

BEHAVIOUR	*'Antony' (male)*	*'Lizzie' (female)*	*'Antony' and 'Lizzie'*
Standing	11.2	11.1	11.1
Sleeping	5.8	3.5	4.6
Preening	38.6	43.8	41.2
Stretch/Scratch	0.4	0	0.2
Shake	0.2	0	0.1
Walking	17.8	20.6	19.2
Digging[δ]	7.5	16.3	11.9
Alert	0.2	0	0.1
Run/Dash	0.2	0.2	0.2
Unison Call	0	0	0
Dancing	0.4	0.4	0.4
Precopulatory Call	0.2	0	0.1
Solicitation	0	0.2	0.1
Nest Building	1.5	0.4	1
Incubating[δ]	15.9	3.3	9.6
Egg Turning	0	0.2	0.1
Total # Daily Obs. (In Sight)	*466*	*461*	*927*
Total # Days Observed	*20*	*20*	*20*

** note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.12: Activity Budget for 'Spree' and 'Cleopatra'

BEHAVIOUR	*'Spree' (male)*	*'Cleopatra' (female)*	*'Spree' and 'Cleopatra'*
Standing	24.5	21.5	23
Sleeping	1.4	2.4	1.9
Preening	53.1	46.7	49.9
Stretch/Scratch	0	0	0
Shake	0.2	0	0.1
Walking	9.6	13.2	11.4
Digging	8.6	13.7	11.1
Alert	0.7	0.5	0.6
Run/Dash	0	0	0
Unison Call	0	0	0
Dancing	1.2	0.7	0.9
Precopulatory Call	0.7	1.2	0.9
Solicitation	0	0.2	0.1
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*429*	*424*	*853*
Total # Days Observed	*20*	*20*	*20*

** note, numbers indicate the % of time in sight that each behaviour was observed*

Table 3.13: Activity Budget for 'Cal' and 'Nelson'

BEHAVIOUR	*'Cal' (male)*	*'Nelson' (female)*	*'Cal' and 'Nelson'*
Standing	20.2	14.6	17.5
Sleeping	1.4	1.7	1.5
Preening	56.1	59.4	57.8
Stretch/Scratch	0.2	0	0.1
Shake	0	0	0
Walking	17	16	16.6
Digging	2	5.7	3.8
Alert	0.9	0.5	0.7
Run/Dash	0.2	0.2	0.2
Unison Call	0	0	0
Dancing	0.7	0.7	0.7
Precopulatory Call	1.1	1.2	1.2
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*440*	*424*	*864*
Total # Days Observed	*20*	*20*	*20*

** note, numbers indicate the % of time in sight that each behaviour was observed*

Table 3.14: Activity Budget for 'Duncan' and 'Aurora'

BEHAVIOUR	*'Duncan' (male)*	*'Aurora' (female)*	*'Duncan' and 'Aurora'*
Standing	16.3	10.4	13.3
Sleeping	5.3	0	2.6
Preening	54.9	48.4	51.6
Stretch/Scratch	0	0	0
Shake	0	0	0
Walking	6	9.6	7.8
Digging$^{\delta}$	11.8	27.9	19.9
Alert	0.5	0.7	0.6
Run/Dash	0	0	0
Unison Call	0.5	0.5	0.5
Dancing	2	2	2
Precopulatory Call$^{\delta}$	2.8	0.5	1.6
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*399*	*405*	*804*
Total # Days Observed	*20*	*20*	*20*

* *note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.15: Activity Budget for 'Lancelot' and 'Gwenivere'

BEHAVIOUR	*'Lancelot' (male)*	*'Gwenivere' (female)*	*'Lancelot' and 'Gwenivere'*
Standing	20.2	16.5	18.3
Sleeping[δ]	0.4	6.6	3.5
Preening	50.3	45.7	48
Stretch/Scratch	0.2	0	0.1
Shake	0	0	0
Walking	17.1	15.6	16.3
Digging	7.4	12.2	9.8
Alert	1.5	1.5	1.5
Run/Dash	0.2	0.2	0.2
Unison Call	0.4	0.4	0.4
Dancing	1.5	0.9	1.2
Precopulatory Call	0.8	0.4	0.6
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*475*	*468*	*943*
Total # Days Observed	*20*	*20*	*20*

* *note, numbers indicate the % of time in sight that each behaviour was observed*

δ *indicates significant difference ($p<0.05$) between proportion of time devoted to behaviour by male versus female crane*

Table 3.16: Activity Budget for 'L'esperance' and 'Susan'

BEHAVIOUR	*'L'esperance' (male)*	*'Susan' (female)*	*'L'esperance' and 'Susan'*
Standing	12.6	10.4	11.5
Sleeping	0	0	0
Preening	73.5	74.8	74.2
Stretch/Scratch	0.4	0.4	0.4
Shake	0	0	0
Walking	8	7.6	7.8
Digging	2.5	4.4	3.5
Alert	0	0	0
Run/Dash	0.4	0.4	0.4
Unison Call	0	0	0
Dancing	1.3	0.8	1
Precopulatory Call	1.3	1.2	1.2
Solicitation	0	0	0
Nest Building	0	0	0
Incubating	0	0	0
Egg Turning	0	0	0
Total # Daily Obs. (In Sight)	*238*	*250*	*488*
Total # Days Observed	*11*	*11*	*11*

** note, numbers indicate the % of time in sight that each behaviour was observed*

3.4 *Discussion*

Cranes behave more normally when humans are not in their view, so the use of blinds for making observations is an important way to conduct research and make decisions regarding the management of the pairs (Swengel et al. 1996). Monitoring crane behaviour using video cameras mounted in their pens is an effective way of obtaining behavioural observations on birds that cannot be watched from blinds, as cranes will adjust quickly to stationary video cameras (Swengel et al. 1996).

Avian behavioural studies often compare the percent of time allocated to specific behaviours in relation to habitats, time of day or year, age, sex, social or reproductive status, or energy expenditures, and usually use interval or continuous sampling methods to make this comparison (Tacha et al. 1985). A study that compared interval and continuous sampling methods for behavioural observations of Sandhill Cranes found that interval sampling methods did not record up to one-quarter of the rare and brief behavioural patterns found using continuous sampling (Tacha et al. 1985). This same study also found that interval sampling tends to underestimate the amount of time spent exhibiting rare and brief behaviours and to overestimate the amount of time spent exhibiting patterns of rare frequency and longer duration (Tacha et al. 1985). As the length of the interval increases, the number of rare and short-duration behaviours not recorded increases (Tacha et al. 1985). This appears to be true for this study as witnessed by the fact that only 16 of 41 known behaviours were observed during the six-week study period.

There is no doubt that continuous behavioural sampling observations could have provided more precise and accurate information than interval sampling (Tacha et al. 1985); however to meet the objectives of this study, an interval sampling methodology was appropriate. It is important to remember that sampling methods must be selected giving due consideration to the project-specific logistics and goals. It would have been possible to use continuous sampling methods for the observation of individual pairs of cranes, but this would have meant a serious reduction in the amount of data available for each pair, who could then be observed only every nine days instead of every two days. As well, our goal was to determine a general idea of what the cranes were doing on a daily basis, and so underestimating the frequency of rare and short-duration behaviours was not important to the study.

Similarly designed studies have been conducted at other captive crane breeding facilities, with behavioural observations conducted for one hour at first light every 2-4days during breeding season to determine the strength of pair bond and make management decisions regarding the future of the pair (Gerencser 1992).

Upon examination of life history data, it appears that rearing method is not a good predictor of breeding success in captive Whooping Cranes. Of the three pairs that bred during the 1999 breeding season, 'Hope' was reared by puppet and 'Chinook' by Whooping Crane parents, 'Antony' was costume-reared and 'Lizzie' was reared by Sandhill Crane surrogate parents, and 'Cal' and 'Nelson' were both costume-reared. While rearing method was a critical predictor in the ultimate breeding success of the Peregrine Falcon, it appears to not play such a role in the Whooping Crane.

In two pairs, the males had sustained injuries that could prevent successful mounting and balancing during copulation, however the females could still be stimulated to lay infertile eggs. 'Nat' suffered from an injured toe that could have prevented mounting during copulation. 'Spree' suffers from a permanently fixed wing that may prevent balancing during copulation. These health conditions might explain the laying of infertile eggs; however, they do not explain the absence of eggs laid. 'Ish' and 'Eha' were recently re-paired in the fall of 1998, as were 'Lancelot' and 'Gwenivere.' As this was their first breeding season together, there may not have been enough time to establish a proper pair bond and therefore breeding was not expected.

Successful copulation did not appear to be linked to environmental cues. The temperature and general weather condition was recorded at the time of observation, and between 1995 and 1999 successful copulations were observed on days that were unseasonably cold, unseasonably warm, windy, calm, overcast, and clear.

Comparisons were made of the behaviour observed among individuals and pairs, between males and females, or when comparing the behaviour of successfully breeding pairs with those that did not breed. All birds spent the highest proportion of time preening. When comparing the proportion of time spent by males and females performing each behaviour, there were no significant differences. The activity budgets of successful pairs were not significantly different from activity budgets in unsuccessful pairs. Each pair exhibited synchronized behaviours with few significant differences. The lack of significant differences observed indicates that breeding success cannot be predicted based on the activ ity budget of the indiv idual or the pair

In the future, undertaking new approaches to understanding or studying captive crane behaviour may provide additional insights into breeding success. Studies that are better able to determine actual synchrony of a pair through use of time-occurrences sampling techniques may provide a better index of pair bonding and propensity to breed successfully.

4.0 Evaluation of Captive Breeding Programs for Whooping Cranes

"Solitude…is so far recognized as valuable only by ornithologists and cranes."

Aldo Leopold, 1953

4.1 *Introduction to the Evaluation*

"Most endangered species programs run as crisis operations – which is, of course, the reason scientists turn to captive breeding" (DeBlieu 1991). When studying endangered species recovery programs, it becomes apparent that the biologists involved spend much of their time working close to the edge of panic (DeBlieu 1991). The two most important approaches to the conservation of endangered cranes is protection of wild habitats and reduction of threats to survival in the wild, however, captive breeding efforts can provide a valuable support to efforts that take place in the field (Mirande 1991). If initiation of captive breeding programs was delayed until it became likely that field-based conservation efforts were failing, these, too would likely fail because little would be known about management of the species in captivity and obtaining individuals would place incredible strain on the declining wild populations (Mirande 1991). In this way, captive breeding programs have become species survival 'insurance policies.'

Captive breeding programs for whooping cranes have met with modest success. The main obstacle is low reproductive success resulting from incomplete understanding of behavioural requirements, husbandry, and facility design. It was only in 1975, after having had cranes in captivity for eight years, that the first pair bred in captivity, and that was with the assistance of artificial insemination (Loftin 1995).

It might be expected that most species of cranes will breed earlier in captivity than in the wild (Mirande et al. 1996a) due to the lack of competition for resources and absence of predation, disease, foraging costs, and other energy-expending activities. Whooping Cranes are one of the few exceptions: in the wild, they can begin laying eggs as early as three years of age, however in captivity most females do not lay until 5-7 years (Kuyt and Goossen 1987, Mirande et al. 1996). The reason for delayed reproduction in captivity is not known.

The current goals of the Whooping Crane captive breeding programs are to increase fertility and hatchability of eggs, increase survivability of chicks and fledglings, to decrease the age of first reproduction, and to create pairs that breed predictably from year to year (C. Mirande pers. comm.). After having kept Whooping Cranes in captive breeding programs for over 30years, and having bred them successfully for 25years, there are still many problems and inconsistencies that must be examined and possibly modified to maximize the success of these programs. Even as our understanding of the life history of the wild population and the husbandry and enclosure requirements of captive populations increases, there still remains a great difference between breeding success in the wild and in captivity.

A goal of this Master's Degree Project was to develop a comprehensive list of factors that potentially affect the breeding of Whooping Cranes in captivity, and to generate recommendations for the captive breeding of Whooping Cranes at the Devonian Wildlife Conservation Centre, to potentially improve breeding behaviour and success. Management recommendations were derived from a detailed evaluation of captive breeding practices at Patuxent, ICF, and DWCC.

There were two specific objectives for the evaluation component of this project:

1. To compare the breeding success and management practices of the Devonian Wildlife Conservation Centre Whooping Cranes with facilities at the United States Government Services Patuxent Wildlife Research Center in Laurel, Maryland, and the International Crane Foundation in Baraboo, Wisconsin, and
2. To develop a comprehensive list of factors that potentially affect the breeding of Whooping Cranes in captivity based on an evaluation of management practices.

4.2 Methods

I compared breeding success and management practices used among facilities with the methods described below. Methods used included: search of historical records, literature review, key informant interviews, and validation procedures for analysis and recommendations.

4.2.1 Breeding Success

Detailed comparisons were made of breeding success using 1999 breeding season data from each of the facilities. Data were obtained through key informant interviews that took place in July and August of 1999 with facility managers. Interviews were conducted in person whenever possible.

However, email contact was used as an alternative. Information obtained included number of breeding pairs, number of eggs laid through natural fertilization, number of eggs laid following artificial insemination, number of chicks hatched, and number reared to fledging. Explanations for reproductive failure were solicited. As well, I obtained data for earlier years from management reports for each facility and discussed breeding history with facility managers. In addition, I was able to obtain data on breeding performance for the wild Canadian population for 1999 through the Canadian Wildlife Service. This information served as a control or standard against which captive breeding success was evaluated.

Interfacility variation in breeding success and comparisons with data for the wild population for the 1999 breeding season were analysed using a G-test of independence, with a Williams' correction for continuity.

4.2.2 Management Practices

I obtained the information necessary to compare facility design, nutrition and health management, and breeding practices through key informant interviews of facility managers, review of management reports and published literature, and through site visits to DWCC and ICF. 'Key informant interviews' is a method that allows the researcher to obtain specialized knowledge through conducting interviews with an individual within an applicable field of expertise (Robson 1993). Key informant interviews were conducted with Whooping Crane keepers, aviculturists, and facility managers at all three captive breeding facilities were conducted to gain an understanding of the facility design and husbandry practices of each facility, as well as to gain a better understanding of captive crane behaviour and understand clues to failure, and determine factors that may influence breeding success in captivity. Information obtained from these interviews included details of enclosures, vegetation, and ponds, construction of pens and indoor shelters, disturbance management practices, dietary components and supplements, health management, and breeding practices including managing of pairs and pair bonds, reproductive techniques, incubation techniques, rearing practices, and methods of minimizing imprinting on release birds.

The wealth of information obtained through key informant interviews was supplemented through an extensive review of facility management reports and published literature. As well, site visits to DWCC and ICF captive breeding facilities afforded the opportunity to examine facility design and management practices.

4.3 Results

4.3.1 Breeding Success

During the 1999 breeding season, the DWCC, ICF, and Patuxent Whooping Cranes laid 13, 20, and 52 eggs, from 3, 4, and 8 females, respectively. The WBNP flock laid 94 eggs from 48 females (Table 4.1). Of these, 2, 7, 26, and 17 chicks survived to fledging from DWCC, ICF, Patuxent, and WBNP, respectively (Table 4.1).

The proportion of egg-laying females was significantly greater in the wild population than in each of the three captive breeding facilities ($p<0.05$) (Table 4.2). Patuxent had a significantly greater number of egg-laying females per total number of females than both DWCC ($p=0.01$) and ICF ($p<0.05$), however there was no significant difference in this ratio between ICF and DWCC ($p=0.6$) (Table 4.2).

I compared the ratios of number of chicks fledged per laying female, and number of laying females per total number of females for each location (Table 4.2). The ratio of chicks fledged per laying female was significantly lower at WBNP than at DWCC, Patuxent, and ICF ($p<0.05$) (Table 4.2). This ratio was significantly higher at Patuxent than at DWCC ($p<0.05$) and at ICF ($p=0.02$), and it was significantly higher at ICF than DWCC ($p<0.05$) (Table 4.2).

Artificial insemination was responsible for 16 of 20 eggs laid at ICF, and 12 of 52 eggs laid at Patuxent (Table 4.1). All 13 of DWCC eggs were naturally fertilized, as they did not employ artificial insemination techniques. Of eggs that were naturally fertilized, 2/13 (15.4%), 0/4 (0%), and 5/40 (12.5%) were broken and 6/13 (46.2%), 4/4 (100%), and 9/40 (22.5%) were infertile at DWCC, ICF, and Patuxent, respectively (Table 4.1). Of eggs that were fertilized through artificial insemination, 5/16 (31.3%) and 4/12 (33.3%) were broken and 2/16 (12.5%) and 2/12 (16.7%) were infertile at ICF and Patuxent (Table 4.1).

Table 4.1: Comparison of Breeding Success at DWCC, ICF, Patuxent, and WBNP

	DWCC	ICF	Patuxent	WBNP
Number of Whooping Crane pairs	9	13	17	~ 83
Number of pairs with breeding potential (both over age 3, in proper health)	5	9	14	-
Number of breeding pairs (1999 or before)	3	9	10	-
number of laying females in 1999	3	4	8	48
total number of eggs laid in 1999	13	20	52	94
number of natural fertilization eggs laid	13	4	40	94
# broken	2	0	5	-
# infertile	6	4	9	-
# fertile, died before pipping	3	0	2	-
# fertile, hatched	2	0	24	46
# of natural fertilization chicks fledged	2	0	22	17
Number of artificial insemination eggs laid	N / A	16	12	N / A
# broken	N/A	5	4	N/A
# infertile	N/A	2	2	N/A
# fertile, died before pipping	N/A	1	1	N/A
# fertile, hatched	N/A	8	5	N/A
# of artificial insemination chicks fledged	N / A	7	4	N / A
Total number of chicks fledged	2	7	26	17

Table 4.2: Summary of Breeding Success at DWCC, ICF, Patuxent, and in the Wild

	DWCC	ICF	Patuxent	WBNP
# of chicks fledged / egg-laying female[α]	2/3 (0.66)	7/4 (1.75)	26/8 (3.25)	17/46 (0.37)
# of egg-laying females / total # of females[β]	3/9 (0.33)	4/13 (0.31)	8/17 (0.47)	48/83 (0.57)

* *note, significant differences calculated using G -test are as follows:*

α WBNP # of chicks fledged/laying female is significantly less than each of DWCC, ICF, and Patuxent ($p<0.05$)

Patuxent # of chicks fledged/laying female is significantly greater than each of DWCC and ICF ($p<0.05$, $p=0.02$, respectively)

ICF # of chicks fledged/laying female is significantly greater than DWCC ($p<0.05$)

β WBNP # of laying females/total # of females is significantly greater than each of DWCC, ICF, and Patuxent ($p<0.05$)

Patuxent # of laying females/total # of females is significantly greater than each of DWCC and ICF ($p=0.01$, $p<0.05$, respectively)

DWCC and ICF # of laying females/total # of females are not significantly different ($p=0.6$)

One frequent problem noted with Whooping Cranes at ICF is that they all exhibit breeding behaviour and yet some do not lay eggs (T. Fry pers. comm.). Similar problems are encountered at DWCC and Patuxent (D. Knapik pers. comm., G. Gee pers. comm.). The average age of onset of egg-laying in female Whooping Cranes at Patuxent is 7 years, which is three or four years later than in the wild (G. Gee pers. comm.). In the past, typically, about 10% of the egg-laying females at Patuxent skip laying in any one year. Recently, concern has been expressed that this number appears to be increasing (G. Gee pers. comm.). In the wild, laying females with strong pair bonds may also skip a year of egg-laying; however, this occurs in a very small percentage of the wild flock and is attributed to nutritional deficiencies on the wintering grounds (B. Johns pers. comm.).

4.3.2 Management Practices

I categorized management practices into aspects of facility design (enclosures, ponds, shelters, disturbance management), nutrition and health management, and breeding practices (mate selection, pair management, reproductive techniques).

4.3.2.1 Facility Design

There are several factors that are typically considered when designing a captive enclosure for breeding endangered species in captivity:

- economic issues including spatial and monetary restrictions,
- maintenance of animal health and prevention of injury,
- efficiency of access by keepers,
- security from predators, escape, and vandals,
- appropriate abiotic requirements including temperature, illumination, and quantity and quality of space, and
- appropriate biotic requirements including food and water and social organization (Bohmke 1995).

Of these parameters, I specifically investigated aspects of the design of enclosures relevant to keeping captive cranes healthy, free from injury, secure from predators and disturbance, and provision of biotic and abiotic requirem ents.

To remain healthy and breed, captive cranes need a clean, safe, and low stress environment (Swengel and Carpenter 1996). At "Crane City," International Crane Foundation, the captive breeding facility consists of an arrang ement of over sixty enclosures arranged along four different 'streets' (Katz 1993). Each enclosure is two separate pens connected to an insulated house, with pairs alternating their habitation of each pen on a yearly basis to minimize accumulation of pathogens and parasites and to allow the soil to rest (Katz 1993). The enclosures at ICF were designed based on a model formerly used at Patuxent, although Patuxent is currently in the process of designing new, larger enclosures. This original design layout was also replicated at the DWCC, although there is only one 'street' as fewer birds are housed at that location.

The following design attributes are present at each facility. Adult crane pens are between 2.3-2.6m in height: high enough to allow for behavioural displays such as dancing and mounting, and low enough so as to prevent full flight from taking place, which can lead to injury (Swengel and Besser 1996). Each pen is covered with flight netting to prevent flighted birds from escaping, and the walls are covered with dark fabric used to provide visual barriers so that adjacent pairs cannot be seen (Katz 1993). Whooping Cranes will fight with neighbouring pairs through the fence if these visual barriers are not present (Swengel et al. 1996). Because one-half of each crane's enclosure is empty at any given time, and empty pens separate adjacent pairs of birds, International Crane Foundation aviculturists have postulated that individuals have the illusion of possessing a much larger territory than they actually do (Katz 1993). Birds are protected from predators by an electric perimeter fence with buried cables surrounding the entire breeding facility (Katz 1993).

Crane pens need to be large enough to prevent a build up of parasitic organisms in the soil and in the shelters (Swengel and Carpenter 1996). At each facility, cranes are normally moved to a fallow pen each year, which allows many soil pathogens to die by removing the potential host (Swengel and Carpenter 1996). Pens allow a minimum of $50m^2$ per crane, which allows sufficient space so cleaning of outdoor pens is unnecessary (Carpenter and Derrickson 1997, Swengel and Besser 1996, Swengel and Carpenter 1996). However, cranes breed best when they have a large, secure, and defensible territory at least $100m^2$ in size (although $300m^2$ is preferable)

(Swengel et al. 1996). ICF and DWCC pens are approximately 233m^2, and the new enclosures at Patuxent are approximately 700m^2. Pen walls provide a visual barrier from adjacent cranes, and are smooth to prevent injury to the cranes (Swengel and Carpenter 1996). Cranes are believed to be more likely to breed when visual barriers are present that isolate them from neighbouring cranes and outside visual disturbances (Swengel et al. 1996, Swengel and Carpenter 1996).

Indoor shelters, approximately 2.25m^2, are necessary at Patuxent, ICF, and DWCC to provide cranes with protection during the winter and harsh weather. Pens are heated at ICF and DWCC during the winter months (Swengel and Carpenter 1996). The floor substrate (typically wood shavings) is cleaned on a daily basis by removing wet shavings and faecal material, to minimize bacterial and fungal growth (Swengel and Carpenter 1996). Several times each year, the shelters are thoroughly cleaned and disinfected (Swengel and Carpenter 1996).

Aviculturists are starting to realize that it is not just the physical features of an enclosure that are critical to promoting breeding behaviour in Whooping Cranes, but also qualitative aspects of the pen environment. Water or marshy areas within enclosures, similar to native and historical breeding grounds, are being incorporated into enclosures because they are thought to play a role in encouraging cranes to breed (Mirande et al. 1996, Swengel and Carpenter 1996). Small (1.5 m diameter) ponds were installed at DWCC prior to the breeding season in 1999. The other facilities have had ponds water bodies in breeding pens for several years (ICF in 1996). The quality of water (e.g., standing versus running, surface area and depth of the pond, and the presence of islands within the pond) may also influence breeding success. Wading ponds either have a continuous flow of water through them (at ICF and Patuxent) or contain standing water cleaned out every 3-5 days (DWCC) to prevent stagnation and bacterial growth (Swengel and Carpenter 1996).

Patuxent is experimenting with building new larger pens with bigger ponds to try to stimulate breeding (G. Gee pers. comm.). These pens are approximately 30.5m by 22.9m with ponds that are 16.8m in diameter (G. Gee pers. comm.). DWCC and ICF enclosures are approximately 15.25m by 15.25m, with 1.5m and 6.1m diameter ponds, respectively (D. Knapik pers. comm., S. Swengel pers. comm.). At DWCC in 1999 two pairs laid eggs for the first time in the presence of recently constructed ponds. A recent experiment at the International Crane Foundation tried to establish a relationship between presence of pond or marsh areas within an enclosure and breeding behaviour. The design consisted of digging ponds approximately 6.1m in diameter with two islands each 1.2m and 1.5m in diameter in the enclosures of seven sexually mature pairs of Whooping Cranes that had not bred previously (Shannon 1996). Islands were raised approximately 5-35cm above water level (Shannon 1996), the same height as nests are traditionally built in Wood Buffalo National Park (Kuyt 1995). Cranes were found to have a significant preference for the pond, as they were six times more likely to be using the pond than using other areas within their enclosure (Shannon 1996). One of the seven pairs laid eggs that year (Shannon 1996).

Pairs at ICF that were given ponds for the 1998 breeding season showed an increase in breeding behaviour and two new pairs laid eggs for the first time (S. Swengel pers. comm.). These ponds were taken away for the 1999 breeding season, because the water made it more difficult to determine if eggs were being laid and broken (Whooping Cranes will often dispose of shells in their ponds), and the possibility existed of an egg being laid and rolling accidentally into the pond (S. Swengel pers. comm.). However, three pairs that laid eggs in 1998 with ponds in their enclosures did not lay eggs again in 1999 when the ponds were removed (G. Archibald pers. comm., S. Swengel pers. comm.).

It is interesting to note that one of the smaller captive breeding centres, the San Antonio Zoo, has enclosures that are quite small compared to the three major breeding facilities, approximately 9m by 12m, however have shallow streams flowing through one end of the enclosure (Lauver 1992). Although these pens are visible to the visiting public, the walkways are elevated from the ground level so that eye level for the birds presents a solid wall (Lauver 1992). Both pairs housed here bred successfully in the 1999 breeding season.

It thought that Whooping Cranes with an open view on one side of their enclosure perceive the viewshed to be a more effective defensible territory. ICF has two pairs of Whooping Cranes with an extended view; breeding or egg laying behaviour in these sexually mature pairs has not been noted (S. Swengel pers. comm.). DWCC pairs all have an extended view yet have low reproductive success. The importance of unobstructed visibility for Whooping Cranes has been established at migratory roosting sites, but similar studies have not been conducted on breeding and wintering grounds (Faanes 1992). Data from the migration studies suggest that Whooping Cranes require a minimum distance of 732m of unobstructed upstream and downstream visibility for roosting (Faanes 1992).

Creating a similar light regime to the native breeding grounds may stimulate reproductive behaviour in captive cranes. George Gee at Patuxent discovered in the mid-1970's that crane species naturally breeding at northern latitudes respond positively to photoperiod manipulation in captivity (Katz 1993). Birds that were exposed to an artificial increase in day length through the use of floodlights mounted on their enclosures showed an increase in breeding behaviours (Katz 1993). Whooping Cranes at Patuxent, and Siberian (Grus leucogeranus) and Hooded Cranes (Grus monachus) have been stimulated to breed by extending photoperiod to a day length typical of their northern breeding grounds (Mirande et al. 1996a, Mirande and Archibald 1990).

4.3.2.2 Nutrition and Health Management

Cranes are typically fed commercial feed adapted from a poultry diet (Swengel and Carpenter 1996). There are three different types of diets given to captive cranes at the three facilities: an adult maintenance diet (given to adult cranes for most of the year), and adult breeder diet (given to adult cranes one to two months before the start of breeding season through to its completion), and starter diets (given to young chicks) (Swengel and Carpenter 1996). DWCC, ICF, and Patuxent all give their cranes the same basic diet, however the overall nutritional composition of the diets differs slightly at the different breeding facilities, because supplemental feeding patterns vary. As well, cranes capture and eat a variety of organisms within their enclosures, including insects and small rodents (D. Knapik pers. comm.). In general, breeder diets are higher in protein and calcium than maintenance diets to bring the cranes into good form for the breeding season (Swengel and Carpenter 1996). Starter diets have higher protein, calcium, vitamin B, and phosphorous levels to facilitate adequate bone and feather growth (Swengel and Carpenter 1996).

In addition to appropriate dietary requirements being met for the various stages of a crane's life history, they are provided with an adequate supply of clean, fresh drinking water (Swengel and Carpenter 1996). Cranes at ICF and DWCC are given water heaters in the winter months to prevent the water from freezing over (Swengel and Carpenter 1996).

Two of DWCC male cranes have physical impairments that could prevent successful breeding. 'Nat' suffered a dislocated toe early in the 1999 breeding season that may have prevented holding during copulation, and 'Spree' has a permanently fixed wing that could prevent mounting and balancing during copulation. In both of these pairs, the females could still be stimulated into laying eggs, however the chances of fertility are reduced. These two mated pairs are ideal candidates for artificial insemination. Patuxent and ICF have birds with similar injuries; these birds are included within their artificial insemination regimes.

'L'esperance' (male), a DWCC male who has been notorious for egg-breaking behaviour since 1997 and was separated from his mate for aggression during the 1999 breeding season, has been observed to enter the molting phase during breeding season several months earlier than most other DWCC birds (D. Knapik pers. comm.). There are also regional differences in behaviour and hormonal physiology being expressed in the different captive flocks. Birds in Calgary and Patuxent undergo simultaneous molting of their flight feathers on a yearly basis, while birds at ICF and in the wild will molt every two years (G. Archibald pers. comm.). There isn't a clear explanation for this phenomenon, however it could provide one reason for the differing levels of breeding behaviour and success exhibited at the three different facilities.

4.3.2.3 Breeding Practices

DWCC, ICF, and Patuxent managers prefer to pair experienced individuals with first-time breeders. Managers usually wait several years for breeding to take place before breaking up a non-breeding pair and attempting to establish new pairs. It is standard practice at all captive breeding facilities to give willing non-breeding pairs the opportunity to practice incubating and rearing a Sandhill Crane chick.

DWCC, ICF, and Patuxent employ a variety of chick-rearing techniques: isolation-rearing, parent-rearing, and hand-rearing. Most chicks at DWCC are isolation-reared, but some are parent- or hand-reared, depending on the management purpose for that chick. Parent-rearing is used when the primary goal is to allow parents the experience of raising and bonding with a chick, in the hope that it will encourage the adult cranes to lay eggs the following season. Whooping Crane chicks are also reared by surrogate parents of a different species. This technique is used when staff is unable to isolation- or hand-rear a bird, and there are no suitable Whooping Crane parents available. Isolation-rearing is used when the primary goal is to raise a Whooping Crane chick to be released to the wild. Hand-rearing is used when a crane chick is injured and the human contact is necessary to ensure proper care.

To assist in the development of normal social behaviour, cranes between the ages of three months and three years are socialized with conspecifics (Swengel et al. 1996). Because DWCC hatches few young each year in comparison to the other captive facilities, they are shipped to either Patuxent or ICF to ensure socializing with an appropriate cohort. The sex of the chicks is determined prior to the period of socializing to ensure that exclusively same-sex groupings are avoided. Care is taken to ensure that chicks that are socialized as colts are not later paired together, as these individuals may recognize one another as siblings and refuse to breed. 'Nat' and 'Christie', a pair at DWCC, have shown no signs of breeding behaviour in the years they have been paired together (1996?). They were hatched on June 5/1992 and June 4/1992 at Patuxent and were both costume-reared (D. Knapik pers. comm.). It is possible that they were socialized as colts together and recognize each other as siblings and are therefore not compatible as a breeding pair.

Artificial insemination is a strategy employed by ICF and Patuxent to improve the fertility of Whooping Crane eggs. Currently, DWCC relies upon only natural fertilization. Young pairs at Patuxent and ICF are allowed to attempt natural fertilization for 1-2 years before beginning artificial insemination (Swengel et al. 1996).

Natural fertilization, although resulting in a decreased percentage of fertile eggs, also decreases the amount of handling and disturbance the birds are subjected to and can reduce the incidence of egg-breakage at the breeding facility. Whooping Cranes that were allowed to experience natural fertilization in the 1999 breeding season broke 2 of 13 (15.4%), 0 of 4 (0%), and 5 of 40 (12.5%) of their eggs at DWCC, ICF, and Patuxent, respectively (Table 4.17). At ICF and Patuxent, where artificial insemination was practised, egg breakage rates of 5 of 16 (31.25%) and 4 of 12 (33.3%) were observed

4.4 Discussion

4.4.1 Breeding Success

The number of eggs produced by laying captive females was twice the number produced by laying wild females. This is a result of the practice of removing eggs produced by captive birds to maximize egg production in excess of what is typical in the wild. However, the proportion of mature females that successfully bred (i.e. produced eggs) was significantly higher in the wild population than in captive birds (0.6 in the wild, 0.4 in captivity). Patuxent had a significantly greater number of egg-laying females per total number of females than both DWCC and ICF, however there was no significant difference between ICF and DWCC. I conclude that the captive populations are still not operating on par with reproductive rates in the wild, however Patuxent has been than more successful than ICF and DWCC. These comparisons are useful to illustrate that all three captive breeding facilities encountered similar difficulties in breeding captive Whooping Cranes, however Patuxent was more effective at bringing females into egg-laying condition.

The lower ratio of chicks fledged per laying female (2.3 vs. 0.4) and per adult female (0.9 vs. 0.2) at WBNP compared to captive breeding flocks was not surprising, given the technique of multiple clutching that is employed in captivity. The higher per capita production of fledglings at Patuxent compared with DWCC and ICF may indicate that the years of experience that Patuxent has at breeding Whooping Cranes and rearing chicks in captivity has lead to an increased success in bringing chicks to fledging, and that DWCC has less success because of limited and recent experience. There are many factors that contribute to chick mortality: malpositioning of the chick, high moisture loss, loss of heat, or disease can all lead leading to death before hatching. Parent-reared chicks are vulnerable to exposure to the elements, disease, and injury sustained within the enclosures. Isolation- and puppet-reared chicks can succumb to malformations of their legs and feet if not provided with adequate exercise.

Increased communication between facilities may allow for more effective transfer of knowledge of breeding and husbandry techniques to other captive breeding facilities. Because Patuxent is more skilled at encouraging female Whooping Cranes to lay eggs, ICF and DWCC may benefit from their knowledge and experience. As the current success of captive breeding programs at the three facilities is poor to modest, husbandry practices vary, and varying opinions exist as to relative importance of factors affecting breeding, it is necessary to come up with a holistic, interfacility approach to the determination of factors that affect the breeding and management of Whooping Cranes.

4.4.2 Management Practices

4.4.2.1 Facility Design

Until the early 1970s, there was little difference between a captive enclosure designed for captive breeding of an endangered species and those for display of common species (Bohmke 1995). The difficulties encountered in many captive breeding programs, however, have drawn attention to the quality of habitat in which the animals are kept, with that hope that habitat enhancement will lead to an improvement in breeding behaviour. It is important that captive design is directed by the goals that the managers are attempting to satisfy (Bohmke 1995). The design of an enclosure to promote breeding in adults is very different from the design of an enclosure to hold birds to be reintroduced to the wild (Bohmke 1995). If the facility is closed to the public, then human aesthetics can be ignored and species-specific practicality can dictate the design (Bohmke 1995). Enclosures that are not open to the public are generally smaller in size, constructed of less expensive materials, and operated more efficiently (Bohmke 1995). Whooping crane captive breeding enclosures, the majority of which are isolated from the public, are smaller and simpler displays than those which house birds on display.

The physical design of an enclosure, including the area, height, building materials, accessibility by predators, and view can influence the breeding behaviour of captive cranes. Crane enclosures must be large enough for birds to feel like they have their own defensible territory. Unfortunately, most conservation centres have a limited amount of space and cannot give cranes territories large enough to mimic the size of a home territory in WBNP.

The aggression observed in DWCC birds in 1999 might be a result of the inclusion of ponds in their enclosures prior to breeding season (G. Archibald pers. comm.). George Archibald feels that water will greatly increase the Whooping Cranes' drive to breed, and if there is a problem with the strength of pair bond it can result in violence (G. Archibald pers. comm.).

If birds are to remain fully flighted, the enclosure must be covered to prevent escape. The height must be great enough that birds can dance and successfully complete the breeding behaviour sequence. If an enclosure is too high, the birds can progress beyond pre-flight behaviour into full flight, which can lead to injuries from collisions with the enclosure walls. Enclosures must also provide an environment safe enough to protect cranes from serious injuries. Attracted to shiny objects, cranes have swallowed nails or other building debris that can be fatal if not quickly removed via surgical procedures. Enclosures must also be secure enough to prevent predators from entering. Whooping Cranes at the DWCC became noticeably agitated when a coyote was patrolling the perimeter, however the cranes were protected by a fenced enclosure within a larger fenced area, to prevent predators from getting too close.

Egg breaking in Whooping Cranes is usually associated with new pairs and females that are laying eggs for the first time (K. Maguire pers. comm.). If Whooping Cranes are breaking their eggs and they are not a part of a new pair or first-time layers, then the problem is usually an extraneous disturbance (K. Maguire pers. comm.). These birds receive triple netting on their enclosures and restrictions are placed on the amount of vehicle traffic that is allowed (K. Maguire pers. comm.). The birds are observed by video camera to minimize human contact (K. Maguire pers. comm.). Often, egg-breakers can be distinguished from other pairs, as they are almost always perceived to be the "skittish" pairs (K. Maguire pers. comm.). A retrospective study at the International Crane Foundation examined eleven years of data on captive cranes subjected to public display, and found that pairs on public display had an elevated rate of egg breakage and a decreased incubation success compared with others that were not on display (Sullivan 1994b).

Cranes that regularly demonstrate an agonistic and aggressive interaction with neighbouring cranes may show an inhibition of breeding behaviour (Mirande et al. 1996a). Several solutions to this problem include placing an empty pen or a pen containing an unrelated species between two conspecific pairs, creating visual barriers, or switching pens (Mirande et al. 1996a, Hutchins et al. 1995, Carpenter 1986). However, territoriality is believed to be an important component in developing a strong pair bond and a confident breeding pair (Katz 1993). If a pair of cranes is kept isolated from other cranes, territorial defence responses may not be stimulated and an otherwise compatible pair may not breed (Katz 1993). It is important for the birds to have distant visual and vocal contact with other cranes (Katz 1993).

Animals in captivity can exhibit behavioural displays that are very different from those in the wild (Katz 1993). Artificial environments characteristic of captive crane facilities may induce exaggeration of certain components of the natural behavioural repertoire (Katz 1993). For example, aggressive displays are commonplace when cranes are defending their territory (Katz 1993). Because cranes in captivity defend a territory hundreds of times smaller than a territory in the wild, with a much more easily patrolled border, aggressive behaviours (towards human caretakers and neighbouring birds) can be far more frequent than cranes would exhibit in the wild (Katz 1993). The possibility exists of a dominant male inhibiting the breeding of other pairs of Whooping Cranes (M. Wellington pers. comm.). When a strong and successful breeding Whooping Crane pair at ICF was separated, the following season three other pairs of cranes began breeding (M. Wellington pers. comm.). This may have been an example of alpha-domination caused breeding suppression, a phenomenon known to occur in other species such as wolves (Mech 1970). Three females at ICF laid eggs in the 1998 breeding season but did not lay in the 1999 breeding season (G. Archibald pers. comm.). This may have been caused by disturbance from very loud, frequently calling neighbouring cranes (G. Archibald pers. comm.).

Birds on public display are less likely to breed than pairs bred in privacy (Mirande et al. 1996, Mirande et al. 1997). Recent observations suggest that perhaps the quality of habitat can overcome the negative effects that public display has on breeding (G. Archibald pers. comm., Shannon 1996). The Amoco Whooping Crane Amphitheatre Exhibit opened in 1995 at ICF. In 1996, they put in the first pair (who had never bred previously). They proceeded to build a nest, but did not appear to lay any eggs (S. Swengel pers. comm.). In 1997, that same pair laid two eggs, which were pulled to induce double clutching, however the pair did not re-lay (S. Swengel pers. comm.). In 1998, they put a new pair of non-breeding Whooping Cranes into the enclosure; they laid eggs in 1999 (S. Swengel pers. comm.). In July of 1999, they put a third pair into the Amoco Exhibit, with the hope that they too will lay eggs in the 2000 breeding season (S. Swengel pers. comm.). It was interesting to note that both pairs of Whooping Cranes that nested built their nests on platforms in the water, which is typical behaviour for wild Whooping Cranes (S. Swengel pers. comm.).

Until recently, birds that were placed on public display were those that were considered genetically well-represented or did not have a suitable mate available, to minimize the overall loss to the population by that bird failing to breed. The Amoco exhibit has changed that, and crane managers and aviculturists now recognize that exhibit as the gold standard to which other enclosures are compared. George Archibald and George Gee (pers. comms.) agree that if money and space were unlimited they would build an Amoco exhibit for every pair in captivity.

4.4.2.2 Nutrition and Health Management

The most important factor for predicting breeding success in wild populations may be the abundance of food, predators, and disease when the young are being raised (Krebs and Davies 1997). In captive populations, this is not a concern because food supplies are abundant and specifically suited to the needs of the parents during egg laying and rearing and the developmental stages of the chick, disease is minimized, and assuming that enclosures have been properly designed, predators are excluded.

There is great uncertainty as to the effect that captive nutrition has on breeding success. Currently, there are studies underway to determine the specific diet of Whooping Cranes on their breeding grounds (B. Johns pers. comm.). It has been shown that the breeding season following a winter with low quality and amounts of available food can result in many pairs failing to nest (Johns 1998a).

There is a species-specific response to the amount of protein in a captive crane's diet. Patuxent has tested a higher protein diet on Sandhill Cranes during the breeding season and found a decrease in egg production (G. Gee pers. comm.). However, Patuxent has also found that by increasing the amount of protein in the diets of birds that were physically capable of breeding but were not producing, four different species of cranes (Blue, Crowned, Sarus, and Hooded Cranes) that previously had no breeding history began breeding in captivity (Katz 1993). ICF Whooping Cranes were observed to lay more eggs in the years they were given fish during AI than the years they weren't (S. Swengel pers. comm.).

Some aviculturists and managers think that the focus should be on trying to learn more about their wild diets and then mimicking it in captivity. There is currently a three-year study underway trying to determine the diet of Whooping Cranes in the wild, although the remoteness of the nesting area, the dense vegetation, and the wet terrain make it extremely difficult to conduct such studies. This study is to conclude in the year 2000, and preliminary results are not yet available, although a previous study indicates that the level of carbon and nitrogen in the wild crane's feather can be attributed to a diet that is more carnivorous than herbivorous, and that the birds are feeding at a fairly high level in the trophic system with fish being a major dietary component (Duxbury and Holroyd 1996).

It has been argued that it is difficult to replicate a wild diet for captive cranes (G. Archibald pers. comm.). George Archibald (pers. comm.) questioned if captive cranes really need as much protein as their wild counterparts because of the general lack of exercise they get in captivity. Crane diets are currently based on poultry feed, originally intended for birds that have a short life during which maximum production is encouraged and poorer quality ingredients are used (G. Archibald pers. comm.). The effect of nutrition on breeding success in captive cranes is worthy of further study.

Researchers studying the Kakapo, a severely endangered New Zealand parrot, are considering the potential applicability of hormone-delivery 'patches' to help encourage birds to breed that might not normally do so as a result of environmental stresses (Reed 1999). If this proves to be successful, perhaps a similar 'patch' could be developed for the Whooping Crane.

In order to successfully breed, Whooping Cranes must be free of severe disease, physical, and hormonal abnormalities. A male crane must be capable of mounting the female, holding on to her back, and balancing by flapping his wings in order to successfully copulate. A female crane must be capable of balancing and supporting the weight of her partner during the act of copulation.

Hormonal changes can affect the behaviour of birds during the breeding season or year-round. In cranes, the breeding season is closely associated with spring migration to the nesting grounds, a result of hormonal responses to a change in light cycle that urge the birds to fly northward (Archibald and Lewis 1996). Breeding behaviour begins normally 2-5weeks before egg-laying, and is therefore concurrent with migration in wild birds (Walkinshaw 1973). Captive birds develop a behavioural pattern described as 'migratory restlessness' during the times of year when wild birds would be migrating northward or southward, which is characterized by an increased amount of walking, pacing, and pre-flight behaviour (D. Knapik pers. comm.). The possibility exists that migratory restlessness, which occurs with greatest frequency and intensity in younger birds, consumes valuable energy needed to breed (S. Swengel pers. comm.).

Molting of flight feathers in Whooping Cranes is triggered by hormonal changes and normally occurs following breeding season but prior to beginning their southward migration (D. Knapik pers. comm.). Birds that molt during what is typically breeding season experience hormonal changes that could lead to egg-breaking behaviour (S. Swengel pers. comm.). Scott Swengel (pers. comm.) has postulated those birds with no intention of breeding molt earlier (during breeding season), although it is possible that they do not breed because they are molting. A cause and effect relationship is difficult to discern. It would be of considerable benefit for future studies to examine the role of hormonal changes on breeding behaviour in captive Whooping Cranes.

4.4.2.3 Breeding Practices

Mirande and Archibald (1990) feel that if properly managed, almost any Whooping Crane (even those that seem incompatible) can be induced to breed successfully in captivity. The use of continual observation, sound husbandry practices, perseverance, and consistent and creative behavioural management techniques developed through a decade of adaptive management can lead to successful pair formation and breeding in the years to follow (Mirande and Archibald 1990). At times, it is important to realize that a pairing is not successful, and to attempt to re-pair the cranes with a more suitable mate (Mirande and Archibald 1990). This mate-switching process can stimulate birds to breed that have not bred previously (Mirande and Archibald 1990).

It is critical to have an understanding of avian social systems if successful captive management and propagation is to take place (Hutchins et al. 1995). Behaviour associated with courtship, mate selection, copulation, nest building, incubation, and parental care is of great importance to avicultural practices because it is so closely linked with reproduction in a species (Hutchins et al. 1995).

There are several genetic issues that should be considered when creating a pair bond. Pair bonds are often selected primarily on the lineage representation of each of the mates, with inbreeding coefficients of each potential offspring calculated from the studbook of captive Whooping Cranes. Because the population reached a low of only fifteen individuals, and the current population is thought to be derived from a founder population of only seven or eight individuals, it is very important that pairs are selected with genetic goals in mind. However, it is also critical to pair birds that are both behaviourally and genetically a good match for one another, to maximize the possibility of successful breeding occurring. It is possible that some individual Whooping Cranes are genetically superior at breeding than others, although this is not currently a criterion used in the selecting of pair bonds. This hypothesis is very difficult to test in a scientific study. If it is a factor in the breeding of captive Whooping Cranes, there is nothing that can be done but to continue to attempt to coax and condition those cranes that do not readily breed into exhibiting natural breeding behaviour. The concept of genetic incompatibility is currently being investigated in cranes, although it is not currently a selection criterion for creation of Whooping

Crane pair bonds either. The theory of genetic incompatibility (Zeh and Zeh 1996, Cunningham and Birkhead 1998) postulates that birds can intuitively sense when a potential mate is a close genetic relation, and therefore will not be stimulated to breed with them (G. Gee pers. comm.). This could be particularly critical in a species with little genetic diversity related to an extremely small size of founder population. This may be a factor that affects the breeding of captive Whooping Cranes, and is worthy of study.

Both age and reproductive experience have been shown to increase the probability of reproductive success in captive cranes (Kuyt 1981, Nesbitt and Wenner 1987, Mirande 1996). It may take dozens of breeding attempts before cranes learn how to copulate successfully (Mirande and Archibald 1990). The male must jump on the female's back, hold on with his claws, and balance by flapping his wings for the act of copulation to occur, while the female supports his weight and maintains her own balance. It is thought that birds of similar ages will pair more readily. A younger bird can be intimidated and dominated by an older adult (Swengel et al. 1996). First time egg-layers are more likely to break their eggs than more experienced breeders (Mirande et al. 1996a). Experience can also change the pattern of egg-laying in mated pairs: the first egg of the season is often laid earlier each year, the number of eggs produced in a season increases, and the breeding season is extended from year to year in breeding pairs (Mirande et al. 1996a). It is also a possibility that the experience gained by introducing crane chicks to rear, or eggs to incubate, can stimulate non-breeding pairs to breed in subsequent years (Mirande et al. 1996a).

There are many behavioural factors that are important to consider in selecting and managing a pair bond including the duration of time together without reproducing, the apparent strength of the pair bond, the balance of dominance between the pair, the behavioural match of the pair, and the benefits and consequences of divorce and re-pairing. Most cranes reach sexual maturity at approximately 2-3years when birds are capable of forming mating pair bonds, although the onset of egg-laying is usually delayed for several years; pairs begin reproducing at 3-5years (Mirande et al. 1996a). The majority of cranes do not produce eggs until 1-2 years after the formation of a pair bond (Mirande et al. 1996a). This is why frequent mate switching can be a disastrous strategy, because cranes may never reach a stage where they are prepared to reproduce if they receive a new mate every two years. DWCC, ICF, and Patuxent all try to wait several years for breeding to take place before breaking a pair bond and attempting repairing.

A study of dominance behaviour in a flock of nine sexually mature Whooping Cranes at Patuxent revealed that captive cranes kept in a large group formed a well-defined linear dominance hierarchy (Kepler 1976). The alpha bird was a male that won every encounter with all other cranes, and ranked immediately below him were three other males (Kepler 1976). The lowest ranking birds in the flock were the five females (Kepler 1976). Dominance within the flock was maintained by physical encounters, threat displays, and avoidance behaviours; dominant birds frequently pecked subordinate birds throughout the course of the study (Kepler 1976). Although there were no obvious pair bonds within the group, and reproductive behaviour was rare, any reproductive behaviour that did occur involved the dominant male (Kepler 1976). When the study was completed, the flock was divided and four pairs were placed in individual breeding pens (Kepler 1976). The dominant male and his mate, the highest ranking female, became the first captive Whooping Cranes to produce eggs in captivity in 1975, and no breeding behaviour was exhibited by the other three pairs (Kepler 1976).

Similar patterns have been noted in chicks that were dominated by pen-mates during socialization as colts; they grow to become submissive adults and exhibited difficulty in pairing and reproducing (Mirande and Archibald 1990). The key to establishing pair formation is establishing a balance in dominance and reproductive drive between the two individuals (Mirande and Archibald 1990). ICF has never had a pair of cranes (of any species) produce eggs where the female was dominant (Mirande and Archibald 1990). However, a male that is excessively dominant can seriously injure or kill his intended mate during copulation attempts. Height relief within the enclosure can influence the dominance relationship. If a very dominant male is being paired with a more submissive female, by placing a mound of dirt in her half of the enclosure during socializing it is possible to increase her dominance to a level that makes her an appropriate behavioural match.

Flock-pairing, achieved by allowing a group of male and female cranes together in a large flock to pair themselves, can have adverse effects on future breeding behaviours of all but the most dominant pair of cranes (Mirande and Archibald 1990). The birds that are not of the first to pair can develop irreversible submissive behaviour patterns that can effectively "ruin" these birds for breeding (Mirande and Archibald 1990). It is ironic that human-chosen pairs, selected for genetic or behavioural reasons, display a much greater rate of breeding success than those birds that w ere allowed to choose their own mate through the flock-pairing method (Mirande and Archibald 1990).

It is difficult to determine if one method of rearing chicks leads to more successful breeding in adults than other methods (S. Swengel pers. comm.). Most costume-reared birds appear to display normal subadult behaviours, but they are only just coming into their reproductive maturity at the present time and it has not yet been determined if they will breed (S. Swengel pers. comm.). Hand-reared birds appear to be better breeders in captivity than parent-reared birds, which could be because they are used to human presence and experience less stress in their enclosures (S. Swengel pers. comm.).

Chicks reared by conspecific parents are usually correctly imprinted on their own species and can remain in captivity for natural breeding at age of sexual maturity (Wellington et al. 1996). Chicks reared by surrogate parents of another species of crane can be difficult to breed in captivity because they are sexually imprinted on their foster species (Welling ton et al. 1996). Parent-reared chicks grow into adults that are very skittish and frightened of humans, which can reduce breeding activity and increase the probability of sustaining injury that physically prevents successful breeding (Mirande and Archibald 1990).

Chicks that were reared by hand or in isolation may be less likely to breed than parent-reared cranes (Derrickson and Carpenter 1987), however most that were socialized with others as colts will learn to breed as adults (Swengel et al. 1996). Hand- and isolation-reared chicks need to see and hear conspecific adults so they learn to socialize and breed with members of the same species (Swengel et al. 1996).

All chicks are socialized with other chicks after fledging. However, interactions with siblings or brood-mates as chicks can establish dominance patterns that have effects that can persist throughout their entire lifetime (Mirande and Archibald 1990). Chicks that were continually dominated by other chicks can become submissive adults and experience difficulty in pairing and reproducing (Mirande and Archibald 1990). It is important to determine the sex of the chicks before socializing begins. If juveniles are grouped according to gender, there can be increased aggression and the potential exists for the formation of homosexual pairs, both of which reduce the chances of breeding as adults (Swengel et al. 1996).

Cranes that were reared or socialized together as colts may learn to recognize each other as siblings (Mirande and Archibald 1990). If these birds are paired together as adults they may appear compatible and seem to have a strong pair bond, but generally will not lay eggs (Swengel et al. 1996, Mirande and Archibald 1990). This strategy is important evolutionarily in that it prevents wild populations from becoming inbred. In captivity, though, birds reared or socialized together may be not at all related, and yet will still recognize one another as siblings and refuse to breed together. The compatible yet non breeding relationship of 'Nat' and 'Christie' may be indicative of socialization as colts together, meaning that they currently recognize one another as siblings. This could explain the compatible relationship and yet a lack of breeding behaviour exhibited in the past years they have been paired together.

Artificial insemination requires a large time commitment from experienced and well-trained staff and places the cranes at risk of physical injury as a result of the handling (Mirande and Archibald 1990). It is possible that if it is administered to cranes that have not yet learned to breed, the procedure may prevent the development of normal breeding behaviour (Mirande and Archibald 1990).

Natural fertilization, although resulting in a decreased percentage of fertile eggs, also decreases the amount of handling and disturbance the birds are subjected to and can therefore decrease the incidence of egg-breakage at the breeding facility. Whooping Cranes that were allowed to experience natural fertilization in the 1999 breeding season had breakage rates between 1/3 and 1/30 of the breakage rates in those birds that were artificially inseminated.

4.4.3 List of Factors Affecting Breeding Success

I compiled a list of factors that may potentially affect the breeding of cranes in captivity from information obtained through evaluations of behaviour of captive cranes at DWCC (Chapter 3), a literature review, and key informant interviews (Chapter 4). The list was presented at the North American Crane Workshop, held in Baraboo, Wisconsin from September 18-21, 1999. This meeting was attended by experts on Whooping Crane captive breeding in North America, including managers, keepers, and aviculturists from Patuxent, ICF, and DWCC, as well as representatives from the Canadian Wildlife Service and U.S. Fish and Wildlife Service Whooping Crane recovery team. Comments from the experts were used to revise and prepare a final list of factors.

In general, although there are many factors that affect the breeding behaviour and success of captive Whooping Cranes, they can be categorized according to whether they are environmental, genetic, or behavioural in nature (Table 4.3). The list of factors presented in Table 4.3 serves as a useful compilation for considering potential improvements to husbandry practices and facility design. Management recommendations based on the list are provided in Chapter 5.

Table 4.3: Factors Affecting Breeding Success of Captive Whooping Cranes

Factor	Classification
Height relief within enclosure	environmental
Presence of water or marshy areas within enclosure	environmental
Quality of water within the enclosure (standing versus running water surface area depth presence of islands)	environmental
Size of enclosure	environmental
Height of enclosure	environmental
Visual barriers or sight lines	environmental
Vegetation type within the enclosure	environmental
Physical hazards within enclosures	environmental
Photoperiod	environmental
Climate	environmental
Physical and health limitations	environmental
Nutrition during breeding season	environmental
Nutrition during the remainder of the year	environmental
	environmental / behavioural
Potential predators	behavioural
Proximity to adjacent or nearby cranes	behavioural
Strength and duration of pair bond (behavioural match of pair)	behavioural
Life history/rearing method (isolation puppet or parent-reared)	behavioural
Imprinting on other species (human or Sandhill Cranes)	behavioural
Mate selection (re-pairing and divorce)	behavioural
Exposure to general public through display	behavioural
Husbandry practices of the individual facilities: artificial insemination or natural breeding	behavioural
Age and experience of the pair	behavioural
Dominance relationship within the pair	behavioural
Method of pairing	behavioural
Hormonal influences	behavioural
Genetic management: inbreeding coefficient lineage and representation	genetic
Pedigree	genetic
Genetic incompatibility	genetic

5.0 Management Recommendations

"Discovery consists in seeing what everybody else has seen and thinking what nobody else has thought."

Albert Szent Gyorgyyi

5.1 Recommendations

The final objective of this Master's Degree Project was to generate management recommendations on husbandry practices and facility design for the Devonian Wildlife Conservation Centre of the Calgary Zoo, to improve breeding behaviour and success of their captive Whooping Cranes. Based on the previous evaluation of factors that can affect the breeding of Whooping Cranes in captivity, I created tables of potentially key environmental (Table 5.1) and behavioural elements (Table 5.2) and recommendations for establishing and promoting successful breeding in captive Whooping Cranes. Since a committee is in place to oversee genetic management of captive breeding populations I did not advance management recommendations on this subject. Management recommendations presented in Tables 5.1 and 5.2 constitute my consideration of an optimum strategy to improve the captive breeding success of Whooping Cranes.

Table 5.1: Environmental Recommendations for DWCC Whooping Cranes

Key aspects of husbandry and facility design	Specific Recommendations
Physical Design of Enclosure	Although the current design or DWCC enclosures is based on those designs of ICF and Patuxent, I recommend tailoring the design to the facility, which is unique with respect to climate and location. The DWCC has an advantage in that, unlike most conservation centers, there is room for expansion and I recommend increasing the size of crane's enclosures to make them as large as facility constraints allow.
	I recommend that parasite load within the enclosures be examined. If these studies show no threat from parasites due to our colder, more northern climate, I recommend that following introduction and socialization, that pairs be given the entire pen rather than just one-half. As well, sanitary concerns should be reduced as pen size is increased.
	I recommend routine visual scanning of enclosures with the aid of a metal detector to locate and remove nails or other harmful building debris before being ingested by cranes. I also recommend investigating more sound building techniques to prevent future metal deposition in the pens.
Quality of Habitat within Enclosure	I recommend further improving the enclosures by increasing the size of the ponds similar to those at ICF and Patuxent (20 feet in diameter and 55 feet in diameter), with islands within the habitat.
	As a result of ponds causing difficulty in monitoring egg-laying behaviour, and because of the possibility that ponds increase drive to breed and can lead to aggression, I recommend increasing the observational staff at the DWCC during the breeding season to ensure that all egg-laying or egg-breaking behaviour is detected and that aggressive attacks of a male can be stopped before serious injury is caused.

Table 5.1 Continued...

Key aspects of husbandry and facility design	Specific Recommendations
Exposure to extraneous disturbances and stress	I recommend relocating 'L'esperance' and 'Susan,' who have broken eggs in past years, to an enclosure on the opposite end of the captive breeding facility which receives less disturbance from DWCC staff.
	Although the Amoco Whooping Crane Exhibit at ICF has been very successful at stimulating cranes to breed, I recommend continuing the practice of keeping only unpaired or genetically well-represented individuals on public display at the Calgary Zoo, and not subject a potential breeding pair to the disturbance of public display.
Nutrition	I recommend increasing the amount of fish given in the Whooping Crane breeding season, to mimic the major dietary component of wild Whooping Cranes, and continue with the standard dry manufactured feed.
	I recommend more research on diets in the wild, and to be flexible in manipulating the captive crane's diet as research results become available.
	Currently, there are no studies underway investigating the effects of varying amounts of protein, carbohydrates, and essential nutrients in captive Whooping Crane's diet on breeding success. I recommend beginning an intrafacility experiment to examine this research question.

Table 5.2: Behavioural Recommendations for DWCC Whooping Cranes

Key aspects of husbandry and facility design	Specific Recommendations
Age and experience of the pair	I recommend pairing individuals that are the same age or within a year or two of one another, to maintain an appropriate dominance balance within the pair.
	There are currently a number of Sandhill Crane pairs kept at the DWCC, however there are not enough to provide incubation support and fertile eggs throughout the entire Whooping Crane breeding season. I recommend increasing the number of Sandhill Crane pairs currently breeding at the DWCC, to provide fertile eggs to give to first-time egg-laying pairs and non-egg-laying Whooping Crane pairs practicing incubation and chick rearing.
Pair bond	I recommend developing a standard behavioural observation protocol to regularly evaluate the strength of pair bonds of captive cranes.
	Because the majority of cranes do not produce eggs until 1-2 years after the formation of a pair bond, I recommend decreasing the frequency of mate switching for reasons of lack of breeding behaviour to a minimum of every 3 years, to allow cranes adequate time to reach the point of reproduction before being given a new mate.
	When rearing more than one chick, I recommend carefully monitoring dominance relationships to ensure that excessive submission does not develop. If this does occur, I recommend removing the dominant chick or chicks so that reproductive drive is not suppressed in the other chicks when they reach sexual maturity.
	When aggressive situations occur like those between 'Ish' and 'Eha' in the 1999 breeding season, I recommend following the strategy of removing and/or reintroducing the aggressive individual from the pair's enclosure rather than the submissive and injured crane. It is impossible to know conclusively, but this could have prevented the second violent attack on 'Eha.'

Table 5.2 Continued...

Key aspects of husbandry and facility design	Specific Recommendations
Method of pairing	Because the data on pairing practices clearly shows that flock-pairing can suppress breeding in all but the dominant pair formed, I recommend that the DWCC continue the practice of force-pairing based on potential behavioural and genetic compatibility.
Proximity to adjacent or nearby cranes	I recommend relocating the most successful breeding pair 'Hope' and 'Chinook' to one end of breeding facility rather than their current central location, to minimize any potential alpha-domination or breeding suppression of adjacent pairs.
Physical (health) limitations	I recommend that 'Spree,' who suffers from a permanently fixed wing, is to be used for artificial insemination to ensure that he has a chance to pass his genes to another generation.
Life history and rearing method	I recommend that a detailed interfacility comparison and statistical analysis be performed to determine if parent-rearing, isolation-rearing, or hand-rearing chicks leads to a significantly greater captive breeding success. Future protocols for raising chicks in captivity should be tailored to the results of this study.
	The sex of chicks should be determined as early as possible so that they can be grouped in both-sex cohorts for socializing, to minimize aggression, and to ensure that homosexual bonds do not form.
	I recommend that 'Nat' and 'Christie' be paired with other cranes prior to the next breeding season. Although Calgary records do not indicate that these birds were ever socialized together, it is likely that because they were hatched from the same cohort they were socialized as colts together and currently recognize one another as siblings.

Table 5.2 Continued...

Key aspects of husbandry and facility design	Specific Recommendations
Husbandry practices	I do not recommend that the DWCC undertake an artificial insemination program until such a time that staff can be increased to enable 24 hour behavioural observations of artificial insemination birds during breeding season. The increased disturbance caused by AI can lead to an increase in egg breakage. Given the current staffing constraints at the DWCC, I recommend that 'Spree' and any other candidates for AI be transferred to Patuxent or ICF and included within their AI regimes.

In general, a successful protocol for breeding Whooping Cranes in captivity will take into account the following general elements, the details of which were discussed in the previous two sections:

- similarity of enclosure to historical native breeding grounds
- the enclosure must meet all requirements so that cranes feel comfortable and that they are in their own defensible territory,
- cranes must be healthy enough (free of disease, physical, or hormonal abnormalities) to be able to properly complete mount, hold, and balance during the breeding behaviour sequence,
- nutritional requirements must be met so cranes are capable of devoting energy required for production and care of offspring,
- cranes must be reared in such a way that they are capable of normal sexual behaviour.
- pairs must exhibit a strong bond with a balance in dominance and aggressive behaviour between the two birds, and
- environmental stimuli including climate and photoperiod must be sufficient to promote hormonal changes associated with breeding season.

Staff at each of the three different captive breeding facilities believes that different factors are of critical importance for improving the breeding behaviour and success of captive Whooping Cranes. George Gee, Director of Patuxent, feels that photoperiod and pen size are the most critical issues to explore in future research because they have the potential to have a very large impact on Whooping Crane breeding behaviour and success (G. Gee pers. comm.). The DWCC conservation staff feels that diet and nutrition may be the key issue that should be explored in trying to improve breeding behaviour and success (G. Tarry pers. comm.). George Archibald at ICF feels that the presence of water within a captive habitat is the key issue that should be studied to improve breeding behaviour and success (G. Archibald pers. comm.). Without further discussion and organization of research efforts, each of the three facilities will continue to explore their own divergent areas of interest.

Research projects to date have been very limited. Initially, the challenge was simply to keep Whooping Cranes alive in captivity, and then the focus became manipulation of variables to try to improve breeding behaviour and success. The difficulty with manipulative studies such as those done with digging ponds in enclosures or increasing photoperiod, is that each year the manipulation is attempted, the mated pairs are all one year older. It is difficult to discern whether an improvement in breeding success is the result of the factor manipulated, or if the birds would have bred that year despite the manipulations. Critical management decisions could not wait for science to catch up, and were made based on hunches of aviculturists and managers, and not based on scientific studies. Sample size is always an issue in endangered species research: there are simply not enough individuals housed at any one facility to allow for large enough sample sizes to conduct statistically valid and significant trials. Data from all facilities is difficult to combine for meta-analyses because of the innumerable factors that vary at each location (including enclosure size, husbandry practices, disturbance, latitude, temperature, climate, photoperiod, and many others).

5.2 Future Studies

There are two major directions that future research studies should take: experimental studies and adaptive management based studies. Although it is very difficult, it is of paramount importance that future decisions regarding the management of Whooping Cranes in captivity be based as much as possible on reliable knowledge established through scientific studies. Sinclair (1991) states that management without the application of the scientific approach inevitably leads to mismanagement. Wildlife management is difficult because often statistically sound models that were based on accurate data can contribute little to the resolution of environmental issues (McNamee et al. 1981). This is why it is so important that when making decisions regarding the future of Whooping Cranes in captivity that both the scientific and the managerial approaches are considered and taken into account. It is critical that in the future, manipulations and adaptive management apply the scientific methods: ask a specific question 'did the treatment make a difference?' and search for the answer.

Typically, this approach involves experimental design and statistical testing of hypotheses. The method would be used to evaluate single factors or the interaction of several factors. The barriers to this approach include the low sample size available and the fact that Whooping Cranes are kept in three facilities that cannot accommodate a complex experimental design.

As is shown many times in the study of ecology, it is rarely just one limiting factor but rather a complex interaction of factors that limit productivity. Captive breeding of Whooping Cranes is likely affected by a complex interaction of factors, and therefore manipulation of a single factor may not provide the required clarity. It is critical for future studies to feature interfacility co-ordination. It is extremely difficult to isolate the cause of a change in breeding behaviour of a captive Whooping Crane. For example, did a pair breed because they were one year older than they were last year, because they had a pond dug in their enclosure, because they could hear another pair calling in the distance, because they couldn't hear another pair calling in the distance, because the winter was mild, because the keepers changed the percentage of protein in their diet, or did they breed for every and any reason listed here?

The key factor is that communication and agreement among facilities is required to evaluate the factors affecting crane breeding. We need at least one facility to investigate the application of multiple factors in husbandry practices and facility design to have a better idea of what affects crane productivity in captivity. For example, it is necessary for a study to be undertaken that combines pen size (what Patuxent believes to be of critical importance), water (what ICF believes to be of critical importance), and nutrition (what DWCC believes to be of critical importance), to see if the interaction of these three key variables can improve the prediction of breeding behaviour and success in captive Whooping Cranes.

Observational studies are one of the most effective ways of acquiring data about study subjects: to watch what they do, and then record, describe, analyze, and interpret the behaviours that were witnessed (Robson 1993). A focus on observational studies would serve to provide very useful information about individual cranes in each of the captive breeding programs.

5.3 Importance of Communication

Whooping Crane recovery is an example of a conservation approach that involves both public- and private-sector organizations and individuals (Cannon 1996). The greatest historical weakness of all conservation efforts to save the Whooping Crane has been administrative in nature (Cannon 1996). The large number of different groups involved (individuals, private organizations, and municipal, state, provincial, and federal units of government in two different countries) means that "the problem of communication, let alone co-ordination, becomes practically insurmountable (Cannon 1996).

Although the number of facilities involved in the captive breeding is relatively small, communication is still fraught with problems. Keepers, aviculturists, and managers get together for a meeting once a year, and this is the main venue for sharing successes and failures in the past year. Unfortunately, the infrequency of communication means that many of the details of day-to-day management practices are never shared with other facilities that could benefit from the experience. As well, much information regarding the intricacies of breeding Whooping Cranes in captivity remains anecdotal in nature and is never published. Those individuals who work one-on-one with the cranes on a daily basis are an invaluable source of information regarding ways to encourage breeding behaviour or methods of strengthening pair bonds, and yet this information is not necessarily exchanged among facilities. The majority of publications are within conference proceedings, published every five to seven years, and little is published in peer-reviewed journals.

Nichols (1977) said that the purpose of a captive breeding program is "to produce not only young birds, but also publications." It is critical to the success of the program that the knowledge, be it intuition or scientifically proven, reach a wider audience by publication of data and results. This will lead to perhaps an easier transition when new sites are initiated for captive breeding Whooping Cranes, to avoid 'reinventing the wheel' or rediscovering through trial and error things that have already been determined by other more established facilities. Japanese Red-Crowned Crane (Grus japonensis) breeders in Europe are sent management surveys and annual inventory questionnaires to gather detailed data on the status, husbandry, reproduction, and mortality of captive cranes (Belterman and King 1993). Perhaps the initiation of a similar survey in Whooping Crane breeders would provide useful information.

There are many biologists who vehemently oppose the release of captive Whooping Cranes into the wild where they may have any contact with the migratory population. Ernie Kuyt, a wildlife biologist who devoted his career in the Canadian Wildlife Service to helping save the Whooping Crane from extinction, feels that any contact between captive-bred birds and the wild population would risk pathological and behavioural "contamination" of the migratory flock (Kuyt 1996a). This is why the reintroduction efforts have focused on new migratory and non-migratory flocks, and not a single bird bred in captivity has been added to the WBNP flock. There are also many who believe that since the Whooping Crane would have survived without the institution of captive breeding programs, that the current programs should be disbanded and reintroduction efforts ceased, to allow the crane to continue fighting the battle on his own. Despite these varying opinions, captive breeding programs persist, with the ultimate goal of creating new migratory and non-migratory flocks from the offspring.

The ultimate goal of this Master's Degree Project was to make recommendations for improving the success of captive breeding programs, which will lead to the release of more Whooping Cranes into the wild, and eventually to the de-listing of Whooping Cranes from the endangered species list, a goal of captive and wild managers, biologists, conservationists, and the general public alike. I am hopeful that if the recommendations for further study are taken into consideration, that the knowledge of factors affecting Whooping Crane productivity will increase substantially in the next few years. It is almost certain that if we can improve our understanding of the relative importance of the various factors that affect breeding in captivity that an improvement of the breeding behaviour and success of the species will follow. This, in turn, will lead to an increase in the number of Whooping Cranes released into the wild. One day, perhaps the Whooping Crane will become a common part of the prairie landscape, ag ain.

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Folk, Marty. Florida State Fish and Wildlife Conservation Commission. September 18 – 21, 1999.

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Gee, George. Director, Patuxent Wildlife Research Center. September 18 – 21, 1999.

Johns, Brian. Wildlife Biologist, Environment Canada. December 2, 1999.

Knapik, Dwight. Crane Keeper, The Calgary Zoo and Devonian Wildlife Conservation Centre. January – September 1999.

Maguire, Kelly. Incubation Specialist, The International Crane Foundation. July 20 – 24, 1999.

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Wellington, Marianne. Chick-rearing Specialist, The International Crane Foundation. July 20 – 24, 1999.

7.0 Appendices

7.1 Crane Observation Checklist / Data Sheet

Date: __________ **Recorder:** ___________ **Time Start/Stop:** __________

Temperature: ___________ **Weather / % Cloud Cover:** ___________

Behaviour Categories	**Pair:**		**Pair:**		**Pair:**	
	Male	**Female**	**Male**	**Female**	**Male**	**Female**
Standing						
Sleeping						
Feather Preening						
Stretching / Scratching						
Feather / Body Shake						
Walking / Pacing						
Digging / Foraging						
Eating / Drinking						
Preflight / Flight						
Alert Behaviour						
Unison Call						
Run / Dash						
Dancing						
Precopulatory Call /March						
Solicitation (wing spread)						
Stepping Up						
Mounting / Balancing						
Copulation						
Dismount, Call, Preen						

Bill Down at Nest						
Nest Building						
Egg Laying						
Incubation						
Egg Turning						
Nest Exchange						
Nest Defence						
Chick Defence						
Chick Feeding						
Chick Brooding						
Bare Skin Expand						
Strutting						
Ruffle Bow						
Crouch Threat						
Hoover						
Pre-Attack						
Charge						
Jump-Rake						
Wing Flap						
Bill Jab						
Cower						
Retreat / Hide						
Out of Sight						

Notes, Comments, Diagrams:

7.2 *Observation Log*

Breeding Behaviours Observed

Tuesday March 30

Attempts: 'Antony' and 'Lizzie' (4/8)
'Hope' and 'Chinook' (8/8)

Thursday April 1

Attempts: 'Antony' and 'Lizzie' (5/8)

Dancing: 'Spree' and 'Cleopatra'
'Ish' and 'Eha'
'Hope' and 'Chinook'

Friday April 2

Attempts: 'Hope' and 'Chinook' (through fence and netting)

Dancing: 'Duncan' and 'Aurora'

Saturday April 3

Attempts: 'Antony' and 'Lizzie' (4/8)
'Antony' and 'Lizzie' (3/8)

Dancing: 'Cal' and 'Nelson'
'Nat' and 'Christie'

* 'Hope' and 'Chinook' lay egg # 1 (C1-1) (infertile). This is the earliest by 2 days that they have ever laid an egg.

Sunday April 4

Attempts: 'Hope' and 'Chinook' (through fence and netting)

Dancing: 'Lancelot' and 'Gwenivere'
'Duncan' and 'Aurora'

Monday April 5

Attempts: 'Antony' and 'Lizzie' (3/8)
'Antony' and 'Lizzie' (5/8)
'Ish' and 'Eha' (1/8)

Dancing: 'Ish' and 'Eha'
'Antony' and 'Lizzie'
'Spree' and 'Cleo'

Tuesday April 6

Attempts: 'Lancelot' and 'Gwenivere' (1/8)

Dancing: 'Duncan' and 'Aurora'
'Lancelot' and 'Gwenivere'
'L'esperance' and 'Susan'

* 'Hope' and 'Chinook' lay egg # 2 (C1-2) (infertile)

Wednesday April 7

Attempts: 'Spree' and 'Cleo' (1/8)
'Antony' and 'Lizzie' (3/8)
'Nat' and 'Christie' (1/8)
'Hope' and 'Chinook' (8/8)

Dancing: 'Cal' and 'Nelson'
'Duncan' and 'Aurora' (through fence and netting)

Thursday April 8

Attempts: 'Hope' and 'Chinook' (through fence and netting)

Dancing: 'Lancelot' and 'Gwenivere'
'Duncan' and 'Aurora'
'Ish' and 'Eha' (through fence)

Friday April 9

Attempts: 'Spree' and 'Cleo' (4/8)

Dancing: 'Spree' and 'Cleo'
'Cal' and 'Nelson'

Saturday April 10

Dancing: 'Lancelot' and 'Gwenivere'
'Duncan' and 'Aurora'
'L'esperance' and 'Susan'

Sunday April 11

Attempts: 'Antony' and 'Lizzie' (4/8)
'Cleo' solicits, 'Spree' doesn't notice (0/8)

Monday April 12

Attempts: 'Hope' and 'Chinook' (through fence and netting)

Dancing: 'Duncan' and 'Aurora'
'Ish' and 'Eha' (through fence)

* later today, 'Ish' and 'Eha' are separated after 'Eha' is found in the building, apparently beaten up by 'Ish.' They have been together for 5 months, but 'Ish' has shown no previous signs of aggression towards 'Eha.' Perhaps this is an attempted mating gone wrong? 'Eha' became scared and cut her head quite badly trying to get through the chain-link fence.

Tuesday April 13

Attempts: 'Hope' and 'Chinook' (8/8)
'Antony' and 'Lizzie' (4/8)
'Cleo' solicits, 'Spree' doesn't notice (0/8)

Dancing: 'Nat' and 'Christie'
'Duncan' and 'Aurora' (through fence and netting)

* 'Ish' and 'Eha' were separated yesterday and put in enclosures with no netting so they could still see one another. Dwight had hoped they would still appear interested in one another (potentially reunite them?) but they are ignoring each other and remaining as far away as possible from the "wall" of the enclosure that they share.

Wednesday April 14

Dancing: 'Duncan' and 'Aurora'

* 'Hope' and 'Chinook' lay egg # 3 (C2-1) (fertile, dies before pipping and does not hatch)

Thursday April 15

Attempts: 'Cal' and 'Nelson' (6/8)
'Antony' and 'Lizzie' (7/8)

* the wooden dummy egg placed in 'L'esperance' and 'Susan's' enclosure several weeks ago was found in their pool. The video camera still hasn't captured which crane is doing it, but Dwight thinks it is 'L'esperance' as he has been seen jabbing at the wooden egg before. Is it possible that 'L'esperance's' hormones are out of whack? He is molting feathers now when he shouldn't be for another month or two.

Friday April 16

Attempts: 'Hope' and 'Chinook' (through fence and netting)

Saturday April 17

Attempts: 'Antony' and 'Lizzie' (1/8)
'Antony' and 'Lizzie' (6/8)
'Spree' and 'Cleo' (3/8)

Dancing: 'Cal' and 'Nelson'

* 'Hope' and 'Chinook' lay egg # 4 (C2-2) (fertile, dies before pipping and does not hatch)

Sunday April 18

Attempts: 'L'esperance' and 'Susan' (1/8)

Monday April 19

Attempts: 'Cleo' solicits, 'Spree' doesn't notice (0/8)

Dancing: 'Cal' and 'Nelson'

Tuesday April 20

Attempts: 'L'esperance' and 'Susan' (1/8)
'Hope' and 'Chinook' (through fence)

Wednesday April 21

Attempts: 'Antony' and 'Lizzie' (6/8)

Dancing: 'Cal' and 'Nelson'
'Spree' and 'Cleo'
'Duncan' and 'Aurora' (through fence)

Thursday April 22

Attempts: 'Duncan' and 'Aurora' (1/8)
'Lancelot' and 'Gwenivere' (6/8)
'L'esperance' and 'Susan' (3/8)
'Hope' and 'Chinook' (through fence)

* 'Hope' and 'Chinook' lay egg #5 (C3-1) (fertile, due to hatch May 22, hatched May 22)

Friday April 23

Attempts: 'Cal' and 'Nelson' (3/8)
'Antony' and 'Lizzie' (7/8)

Saturday April 24

Attempts: 'L'esperance' and 'Susan' (3/8)
'L'esperance' and 'Susan' (1/8)

Dancing: 'L'esperance' and 'Susan'

Sunday April 25

Attempts: 'Cleo' solicits, 'Spree' doesn't notice (0/8)
'Hope' and 'Chinook' (2/8)

* 'Hope' and 'Chinook' lay egg # 6 (C3-2) (fertile, due to hatch May 25, hatched May 24)
* 'Antony' and 'Lizzie' lay egg # 1 (L1-1) (infertile)
* 'L'esperance' and 'Susan' are separated (they have been together for 3-4 years). He was chasing her relentlessly around the enclosure and she was getting scared (but she was not hurt).

Monday April 26

Attempts: 'Lancelot' and 'Gwenivere' (1/8)

* Dwight tried to reintroduce 'Ish' and 'Eha,' and left them alone for about fifteen minutes. When he returned, 'Eha' was in the building, injured worse than the previous time. It appears that 'Ish' has become overly aggressive with 'Eha' and they will not be placed together again.

Tuesday April 27

Attempts: 'Cal' and 'Nelson' (3/8)
'Hope' and 'Chinook' (8/8)

Dancing: 'Cal' and 'Nelson'

Wednesday April 28

Attempts: 'Lancelot' and 'Gwenivere' (4/8)

Dancing: 'Duncan' and 'Aurora'
'Lancelot' and 'Gwenivere'

* 'Hope' and 'Chinook' lay egg #7 (C4-1) (infertile)

Thursday April 29

* observations cancelled due to inclem ent weather

Friday April 30

Attempts: 'Cal' and 'Nelson' (6/8)

Dancing: 'Cal' and 'Nelson'

* 'Antony' and 'Lizzie' lay egg #2 (L1-2) in the opposite corner of where the first egg was laid near the pond (fertile, due to hatch out May 30, died before pipping)
* Dwight tried to reintroduce 'L'esperance' and 'Susan' but as soon as he put her back in the enclosure, 'L'esperance' began chasing her around again. He took 'Susan' out of the enclosure before she was injured.

Saturday May 1

Attempts: 'Duncan' and 'Aurora' (1/8)
'Duncan' and 'Aurora' (3/8)

* 'Hope' and 'Chinook' lay egg # 8 (C4-2) in the near vicinity (<2 m.) of the pool, same as the previous 7 eggs (fertile, due to hatch out May 31, found a few broken pieces of shell in the pool May 18)

Sunday May 2

Attempts: 'Cleo' solicits, 'Spree' doesn't notice (0/8)

Dancing: 'Cal' and 'Nelson'

Monday May 3

Dancing: 'Lancelot' and 'Gwenivere'
'Duncan' and 'Aurora'

Tuesday May 4

Attempts: 'Cal' and 'Nelson' (5/8)

Wednesday May 5

Attempts: 'Lancelot' and 'Gwenivere' (1/8)

Dancing: 'Lancelot' and 'Gwenivere'
'Duncan' and 'Aurora'

Thursday May 6

Attempts: 'Cal' and 'Nelson' (1/8)

Friday May 7

Attempts : 'Cal' and 'Nelson' (1/8)

Dancing: 'Cal' and 'Nelson'
'Nat' and 'Christie'

Saturday May 8

Attempts: 'Lancelot' and 'Gwenivere' (5/8)
'Lancelot' and 'Gwenivere' (6/8)

Sunday May 9

Attempts: 'Lancelot' and 'Gwenivere' (4/8)
'Lancelot' and 'Gwenivere' (3/8)
'Lancelot' and 'Gwenivere' (6/8)

Dancing: 'Duncan' and 'Aurora'

~end of observations~

** May 22 and May 24 'Antony' and 'Lizzie' recycled and laid two more eggs (L2-1, L2-2) (infertile)*

Management of Captive Whooping Cranes (Grus americana) to Improve Breeding Behaviour and Success

Investigator:

Jennifer L. White: *Primary Investigator, Faculty of Environmental Design, University of Calgary*
Committee Chair: *Dr. Cormack Gates, Faculty of Environmental Design, University of Calgary*
Committee Member: *Dr. Gordon Court, Alberta Environmental Protection, Edmonton, Alberta*

Funding Agency:

University of Calgary, Faculty of Environmental Design Graduate Research Scholarship

Informed Consent:

This consent form, a copy of which has been given to you, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, please ask. Please take the time to read this form carefully and to understand any accompanying information.

The purpose of this Master's Degree Project is to evaluate the current and past habitat and breeding behaviour of nine captive breeding pairs of adult Whooping Cranes (Grus americana), and to provide recommendations for habitat enhancement to potentially increase incidences of breeding and copulatory behaviour within the captive population. This analysis will assist the Calgary Zoo and the Devonian Wildlife Conservation Centre in making decisions regarding future habitat modifications for the captive cranes, and may have an impact on the overall breeding success of the species in captivity.

You have been chosen to participate in this research project because of your current or previous involvement with Whooping Crane or other endangered species conservation and captive breeding throughout North America. The participation of experts in the field of endangered species conservation is critical to the successful completion of the research project, as a vast majority of the knowledge of Whooping Crane breeding behaviour remains anecdotal and unpublished by those primarily responsible for their care.

It is not anticipated that you will experience any discomforts or inconveniences associated with your participation. The time commitment is minimal. There are no known or suspected short- or long-term risks associated with your involvement with the research project.

If you agree to participate in this research project, you will be interviewed over the phone or in person (if geographically permissible). You may also be asked to review the results of behavioural observations taken during the 1999 breeding season at the Calgary Zoo Ranch and comment on their relative normalcy compared to wild or other captive flocks. Your commitment will involve approximately one hour of your time devoted to the initial interv iew.

It is anticipated that all relevant information will be obtained during this initial interview, however if further issues arise that require continued exploration, you may be approached for a second interview. You also may be approached to verify the transcription of facts obtained from the first interview. Participation in the first phase of interviews in no way obligates you to participate in further interv iews.

All attempts will be made to obtain information first and foremost from the relevant published literature. Any information sought from interviews will be supplemental information that was not available in the published literature.

The researcher and primary investigator, Jennifer White, is the only person who will have access to the information provided in the interviews and it will be used solely for the purposes outlined. If you choose to participate in the interview process but wish to remain anonymous, your anonymity will be guaranteed. If you wish to see a transcription of the interview to verify its contents, a copy will be forwarded to you. All information obtained from the interview will be transcribed into a word processing document, and files will be stored on computer disk and hard copy for a period of three years following the interview. At this time, all computer files will be erased and hard copies w ill be shredded. These files w ill only be accessible to the inv estigator.

There are no expected financial costs that will be incurred as a condition of, or because of, your participation in the research.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive your legal rights nor release the investigators, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time. Your continued participation should be as informed as your initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you have further questions concerning matters related to this research, please contact:

Jennifer White: (403) 270-9649

If you have any questions concerning your participation in this project, you may also contact the Environmental Design Research Ethics Committee:

Prof. Theresa Baxter: (403) 220-6601

______________________________ ______________________________

Participant Date

______________________________ ______________________________

Investigator/Witness Date

A copy of this consent form has been given to you to keep for your records and reference.