NESTING SUCCESS OF COLONIAL TREE-NESTING WATERBIRDS ON SELECTED WETLANDS IN NORTHEAST SOUTH DAKOTA

BY

Nathaniel J. Baker

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NESTING SUCCESS OF COLONIAL TREE-NESTING WATERBIRDS ON SELECTED WETLANDS IN NORTHEAST SOUTH DAKOTA

This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Dr. Charles D. Dieter
Thesis Advisor Date

Dr. Kristel K. Bakker
Thesis Advisor Date

Dr. Volker Brozel
Head, Department of Biology/Microbiology Date

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ABSTRACT

NESTING SUCCESS OF TREE-NESTING WATERBIRDS IN COLONIES ON SELECTED WETLANDS IN NORTHEAST SOUTH DAKOTA

Nathaniel J. Baker

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The northern Great Plains of North America provides the primary breeding habitat for numerous species of waterbirds. Reproductive status and population parameters of colonial tree-nesting waterbirds are largely unknown within the prairie pothole region. Objectives of this study were to: (1) evaluate nesting and fledging success of colonial tree-nesting waterbirds on selected wetlands in northeast South Dakota, (2) assess overall colony nesting and fledging success of colonial tree-nesting waterbirds breeding on selected wetlands in northeast South Dakota, and (3) identify important local and landscape habitat characteristics necessary for colonial tree-nesting waterbird populations on wetlands of northeast South Dakota. During the 2008 and 2009 breeding seasons I monitored nesting success of black-crowned night heron (*Nycticorax nycticorax*), great blue heron (*Ardea herodias*), cattle egret (*Bubulcus ibis*), great egret (*A. alba*), snowy egret (*Egretta thula*), and double-crested cormorant (*Phalacrocorax auritus*) on wetlands in northeast South Dakota.

I monitored 28 colonies in 2008 and 25 in 2009, 14 of which were monitored in both years. Colonies were visited once every 6 - 8 days throughout the 2008 and 2009

breeding seasons. I monitored a total of 1,174 and 1,376 individual nests with a 20-60x82 spotting scope at a distance of 100 - 150 m to mitigate observer disturbance from 15 April – 15 August in 2008 and 2009, respectively. I evaluated the apparent nest and fledge success for all 6 study species. Overall, nest and fledge success were, black-crowned night heron (52.1%, 47.9%), great blue heron (58.2%, 35.9%), cattle egret (73.1%, 69.2%), great egret (61.5%, 50.7%), snowy egret (83.6%, 81.7%), and double-crested cormorant (70.4%, 54.2%), respectively. Colony nesting success was significantly different ($p<0.05$) between years in 6 of the 14 colonies, while colony fledging success was significantly different ($p<0.05$) between years in 4 colonies.

Nest abandonment was the leading cause of nest failure and ranged from 34.7% of total failures in black-crowned night heron to 64.3% in cattle egret, with a mean of 47.6% for all species combined. Nest structure was the second highest leading cause of nest failure, which accounted for a mean of 30.4% for all species. Great blue herons had the highest rate of nest takeover, 37.3%, solely attributed to double-crested cormorants. There were 1,234 (48.4%) of the monitored nests that did not fledge any young while successful nests had a fledging rate of 77.2%. The highest sources of fledge failure were primarily attributed to nest structure failure and young dying within the nest.

I surveyed local vegetation characteristics at 27 of the 39 active colonies monitored when all nesting was completed. I also surveyed 32 non-nesting sites within the study area that were deemed to contain suitable nesting habitat. I measured land use characteristics in 5 concentric rings expanding from the center of each colony and non-

nesting site to assess how landscape attributes affect colony site selection, and nest and fledge success. Buffer distances used were 400 m, 800 m, 1600 m, 3200m, and 6400 m. Land cover was obtained by using the 2001 National Land Cover Database.

Colony site locations of black-crowned night heron, cattle egret, great egret, and snowy egret were almost exclusively located on islands. These locations were positively associated with bare ground and water surrounding colonies, and negatively associated with herbaceous vegetation within colonies. Great blue herons selected sites that contained green ash trees (*Fraxinus pennsylvanica*) and were surrounded by a high percentage of herbaceous wetland area. Double-crested cormorant colony locations were positively associated with bare ground on island colonies, open water, and total wetland area. The best colony site predictive models for all species contained both local and landscape variables, while nest success models were variable. However, nesting success for all species was positively influenced by increased bare ground occurring within colonies and the amount of open water and wetland area surrounding colonies.

According to my findings, the low reproductive success of black-crowned night herons and great blue herons suggests that these breeding populations in northeast South Dakota are declining. Cattle egret, great egret, snowy egret, and double-crested cormorant reproductive success is relatively high in northeast South Dakota, but other than the double-crested cormorant their breeding numbers are relatively low. Predictive colony site and nest success models created for all species indicate that management practices should be conducted at both the local and landscape levels.

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CHAPTER 1

INTRODUCTION

Introduction

There has been little research conducted on colonial tree-nesting waterbirds in the Great Plains or specifically, in South Dakota. Waterbirds that nest in South Dakota are migratory with many wintering along the southern coasts of the U.S. and into Central and South America. The Prairie Pothole Region (PPR) of North America, comprising approximately 715,000 km^2 (Euliss et al. 1999), provides excellent habitat for raising young. The PPR is well known for its reputation as "the duck factory of North America," but it is equally important for nesting waterbirds (Weber et al. 1982, Kantrud and Stewart 1984, Naugle 1997). South Dakota is particularly important as approximately 65% of wetland basins have been retained, while other prairie states have lost nearly all of them (Beyersbergen et al. 2004). Within South Dakota, the highest wetland density occurs in the northeastern portion of the state where temporary, seasonal, and semipermanents wetlands occur in areas that number over 210, 180, and 30 basins per 25.9 km^2, respectively (Johnson et al. 1997). Naugle et al. (1996) noted the high density of wetlands in northeast South Dakota that contained inundated trees, which are potential nesting sites for colonial tree-nesting waterbirds. However, continued degradation and loss of wetland habitat has created worldwide concern for waterbird populations (Parnell et al. 1988, Kushlan 1992, Carney and Sydeman 1999, Beyersbergen et al. 2004, Bakker 2005).

Colonial tree-nesting waterbirds are dependent upon aquatic habitats for a substantial portion of their life history (Beyersbergen et al. 2004). These aquatic habitats are essential for both nesting and foraging. Habitat quantity and quality reduction are among the greatest threats to colonial waterbirds (Parnell et al. 1988). Habitat loss is especially evident in the northern Great Plains, where agriculture has replaced and fragmented much of the native vegetation. Furthermore, remaining wetlands are often degraded by agricultural runoff from surrounding uplands (Dieter 1991). Due to habitat quantity and quality reduction, waterbird populations are likely to fluctuate greatly within the PPR (Niemuth and Solberg 2003).

Waterbird Population Status

Waterbird populations drastically declined during the early part of the twentieth century due to unregulated harvest fueled by the commercial plume trade. During this time, millions of adult herons and egrets were killed during the breeding season for their feathers (Kushlan and Hafner 2000). During the 1960s, several populations of waterbirds again experienced steep declines due to widespread use of dichlor-diphenyl-trichlorethylene (DDT) which resulted in thinning of eggshells (Kushlan and Hafner 2000). Although most waterbirds have overcome these detriments, the rapid loss and degradation of habitat still threaten populations.

Several coordinated efforts have been initiated in response to concern over colonial waterbirds. The U.S. Fish and Wildlife Service and the Canadian Wildlife Service have coordinated and implemented the North American Waterbird Conservation Plan (NAWCP)

(Kushlan et al. 2002). The Northern Prairie and Parkland Waterbird Conservation Plan (NPPWCP) is a regional plan developed by the Prairie Pothole Joint Venture (Beyersbergen et al. 2004) under the Waterbird Conservation for the Americas initiative. The continued well being of colonial waterbirds requires that resource managers at all levels focus research efforts on this guild (Parnell et al. 1988). Conservation priorities should be focused in areas with the highest amounts of native lands still intact, as many priority species require large tracts of habitat (Parnell et al. 1988).

The South Dakota Comprehensive Wildlife Conservation Plan (SDCWCP) (SDGFP 2006) states that a key element of this plan is to assess "locations and relative conditions of key habitats and community types essential to conservation of species of greatest concern". Wetlands located in northeast South Dakota have been identified as the "best of the best" remaining habitat for nesting waterbirds in South Dakota (N. Drilling. Pers. Comm.). Numerous species of colonial waterbirds that breed in South Dakota are classified as moderate or high concern by the NPPWCP (Beyersbergen et al. 2004) and the NAWCP (Kushlan et al. 2002). Several waterbirds have also been listed as Level I or II priority in the South Dakota All Bird Conservation Plan (SDABCP) (Bakker 2005). Level I species have the highest conservation priority due to: high maximum abundance of the species within its range in South Dakota, South Dakota constitutes the core of the species within its range, and/or the species is showing population declines in South Dakota or across its range (Bakker 2005).

Species Distribution and Abundance

There are 33 species of colonial and semi-colonial waterbirds that breed in South Dakota (Tallman et al. 2002, Drilling 2007). The highest breeding densities of these species occur in northeast South Dakota. Drilling (2007) found 6 species of colonial tree-nesting waterbirds, black-crowned night heron (*Nycticorax nycticorax*), great blue heron (*Ardea herodias*), cattle egret (*Bubulcus ibis*), great egret (*A. alba*), snowy egret (*Egretta thula*), and double-crested cormorant (*Phalacrocorax auritus*), nesting in wetlands of northeast South Dakota.

Black-crowned Night-Heron

The black-crowned night heron (BCNH) is a cosmopolitan species that breeds on every continent except Australia and Antarctica (Davis 1993). Within South Dakota, its range is primarily restricted to the northeastern portion of the state (Tallman et al. 2002, Drilling 2007). Historically, BCNHs were hunted for food, and have been shot and trapped as pests in fish hatcheries. During the 1960s, several populations drastically declined due to DDT (Davis 1993). Pesticides resulting in indirect adult mortality and direct mortality of eggs and young coupled with wetland loss and degradation were primary causes for this species decline (Beyersbergen et al. 2004).

Black-crowned night-herons are listed as a level I priority species in South Dakota as their population is declining (Bakker 2005), and are listed as having moderate conservation concern across its range under the North American Waterbird Conservation Plan (Kushlan et al. 2002). The Northern Prairie and Parkland Waterbird Conservation Plan

also list BCNH as a species of moderate concern according to conservation vulnerability rankings (Beyersbergen et al. 2004). In South Dakota, BCNHs nest in trees and in large cattail and bulrush marshes, while feeding in rivers, streams, lakes, and sloughs (Tallman et al. 2002). Estimated breeding population in northeast South Dakota was approximately 82 pairs in 6 colonies in 2007, and breeding colonies ranged in size from 2 to 103 nests (N. Drilling unpub. data).

Great Blue Heron

The great blue heron (GBHE) is considered one of the most widespread and adaptable wading birds in North America (Butler 1992), and is a common summer resident in eastern South Dakota (Tallman et al. 2002). Great blue herons have the widest breeding range of colonial tree-nesting waterbirds in South Dakota (Drilling 2007). Nesting habitat includes large trees adjacent to water and slow-moving to calm, shallow water for feeding (Beyersbergen et al. 2004). Great blue heron populations are assumed to be declining; however exact population numbers are unknown. Conservation status of GBHE is regionally specific. In the Western Hemisphere, GBHEs are not currently listed as a species of conservation concern (Kushlan et al. 2002), but in the PPR, GBHEs are classified as a species of moderate vulnerability concern (Beyersbergen et al. 2004). In South Dakota, GBHEs are listed as a level II priority species as they have medium abundance scores (Bakker 2005). Estimated breeding population in the study area was approximately 304 pairs in 41 colonies in 2007. Breeding colonies ranged in size from 1 to 87 nests (N. Drilling unpub. data).

Cattle Egret

Cattle egret (CAEG), an exotic species, is extremely widespread and adaptable to both aquatic and terrestrial environments (Telfair 1994). Cattle egrets arrived in the U.S. in 1941 and nesting was documented in 1953 (Kushlan and Hancock 2005). The CAEG is a gregarious species often observed foraging with grazing animals. Cattle egrets are the most widespread and abundant heron worldwide, rapidly expanding their range throughout the Western Hemisphere during the twentieth century. Cattle egrets are a common summer resident in northeast South Dakota, inhabiting pastures and wetland edges, breeding in large wetlands, and nesting in shrubs and trees (Tallman et al. 2002). Conservation status of the CAEG is not currently at risk for their cosmopolitan distribution (Kushlan et al. 2002). However, CAEGs have been documented to show twice the amount of aggression toward other nesting species and win more nesting disputes than native species (Burger 1978). Increasing CAEG populations could lead to a higher conservation priority rating if they are, in fact, displacing native waterbird species. Estimated breeding population within the study area consisted of approximately 378 pairs in 7 colonies in 2007. Breeding colonies ranged in size from 18 to 468 nests (N. Drilling unpub. data).

Great Egret

The great egret (GREG) is a cosmopolitan species that inhabits freshwater, estuarine, and marine wetlands, nesting in woody vegetation, shrubs, and trees (McCrimmon et al. 2001). In South Dakota, the GREG is a common summer resident in the northeast, nesting and feeding in sloughs, marshes and flooded pastures (Tallman et al.

2002). In South Dakota, GREGs are found almost exclusively on marshes and wetlands east of the Missouri River (Drilling 2007). Populations appear to be stable or slightly increasing across their range (McCrimmon et al. 2001). The North American Waterbird Conservation Plan does not list this species as being at any conservation risk (Kushlan et al. 2002). However, the (NPPWCP) lists GREG as a low risk vulnerable species (Beyersbergen et al. 2004). Great egrets are not listed as a species of concern in South Dakota (Bakker 2005). Estimated breeding population within the study area consisted of approximately 963 pairs in 11 colonies in 2007. Breeding colonies ranged in size from 4 to 559 nests (N. Drilling unpub. data).

Snowy Egret

The snowy egret (SNEG) inhabits shallow estuarine sites, swamps, freshwater lakes, and marine habitats. In South Dakota, this species is a locally common summer resident in the northeast, nesting in woody vegetation within marshes and sloughs (Tallman et al. 2002). Like most heron species, SNEGs feed on a wide array of prey items found in marshes and sloughs (Parsons and Master 2000). Conservation status of the SNEG in the Western Hemisphere is of high concern (Kushlan et al. 2002), but within the PPR their conservation status is set at a low vulnerability risk (Beyersbergen et al. 2004), as SNEGs only breed in isolated locations of the PPR, most notably in northeast South Dakota (Parsons and Master 2000). Snowy egrets are not listed as a species of concern in South Dakota (Bakker 2005). Estimated breeding population within the study area consisted of

approximately 190 pairs in 4 colonies in 2007. Breeding colonies ranged in size from 18 to 266 nests (N. Drilling unpub. data).

Double-crested Cormorant

The double-crested cormorant (DCCO) is the most numerous and widely distributed species of all North American cormorants (Hatch and Weseloh 1999). Populations have rapidly increased across North America since the mid 1970s (Weseloh et al. 1977, Scharf and Shugart 1981, Milton and Austin-Smith 1983, Hatch 1984, Ludwig 1984, Vermeer and Rankin 1984, Craven and Lev 1987, Chapdlaine and Bédard 1995, USFWS 2003). This abundance has resulted in increased conflicts with both biological and socioeconomic resources such as recreational fisheries, other birds, vegetation, and aquaculture (USFWS 2003). Due to their increasing abundance, DCCOs are listed as a species of low concern under the NPPWCP (Beyersbergen et al. 2004). Within South Dakota, DCCOs are considered a common summer resident in the northeast, inhabiting lakes and rivers, and nesting in dead trees (Tallman et al. 2002).

Double-crested cormorants differ from other cormorants in that they occupy inlands, such as freshwater wetlands and lakes as well as coastal areas. Among colonial tree-nesting waterbirds in South Dakota's wetlands, DCCOs are by far the most numerous (Drilling 2007). Estimated breeding population within the study area consisted of approximately 3,962 pairs in 62 colonies in 2007. Breeding colonies ranged in size from 1 to 1,762 nests (N. Drilling unpub. data).

Objectives

Identification of key habitats at all relevant scales is necessary to understand species distribution patterns across the landscape (Weins et al. 1986, Gibbs and Kinkel 1997), and to predict how various anthropogenic disturbances affect waterbird populations (Hansen et al. 1993). Evaluating both nesting and fledging success as well as local and landscape habitat characteristics that influence colony site selection, nesting and fledging success are necessary to understand distribution patterns and predict how anthropogenic and land use activities and practices affect waterbird populations. Evaluating reproductive success is essential in understanding the breeding biology and behavior of waterbird species, as well as assessing and managing waterbird populations (Burger 1982). Therefore, the objectives of this study were to: (1) evaluate nesting and fledging success of colonial tree-nesting waterbirds, BCNH, GBHE, CAEG, GREG, SNEG, and DCCO, breeding on selected wetlands in northeast South Dakota as suggested in the SDCWCP (SDGFP 2006) and SDABCP (Bakker 2005), (2) assess overall colony nesting and fledging success of colonial tree-nesting waterbirds breeding on selected wetlands in northeast South Dakota, and (3) identify important local and landscape habitat characteristics necessary for colonial tree-nesting waterbird populations on wetlands of northeast South Dakota.

CHAPTER 2

STUDY AREA AND METHODS

STUDY AREA

This study was conducted in northeast South Dakota, which lies in the Northern Glaciated Plains ecoregion containing both the Tallgrass and Mixed grass prairie subregions (Figure 2-1). This area is comprised of a flat to gently rolling landscape with subhumid conditions where the tallgrass and shortgrass prairie transitional zone occurs (Bryce et al. 1998). This region contains high densities of temporary, seasonal, and semipermanent wetlands as classified by Cowardin et al. (1979). Temporary wetlands number 520,379 in eastern South Dakota covering 157,827 hectares, seasonal wetlands number 334,699 and encompass 223,994 hectares and semipermanets total 23,997 occupying 152,809 hectares (Johnson et al. 1997). Semipermanents are mostly (n= 11,828) found in Marshall, Day, Roberts, Grant, and Deuel counties of northeastern South Dakota, and there are 603 permanent wetlands in eastern South Dakota covering 78,509 hectares (Johnson et al. 1997).

I evaluated nesting and fledging success of colonial tree-nesting waterbirds on riparian and wetland ecosystems within the 2 aforementioned subregions. Regions of South Dakota vary in density and type of wetlands and rivers (Johnson et al. 1997, Bakker 2005). These regions also vary in importance for breeding colonial waterbirds. Drilling (2007) defined the Prairie Coteau Region as the highest importance area, followed by the Lake

Thompson Watershed Region and the Northern Potholes Region. My study area included the entire Prairie Coteau and Lake Thompson Regions, with the exception of Lake County, as well as the eastern third of the Northern Potholes and the extreme northeastern portion of the Southern Potholes.

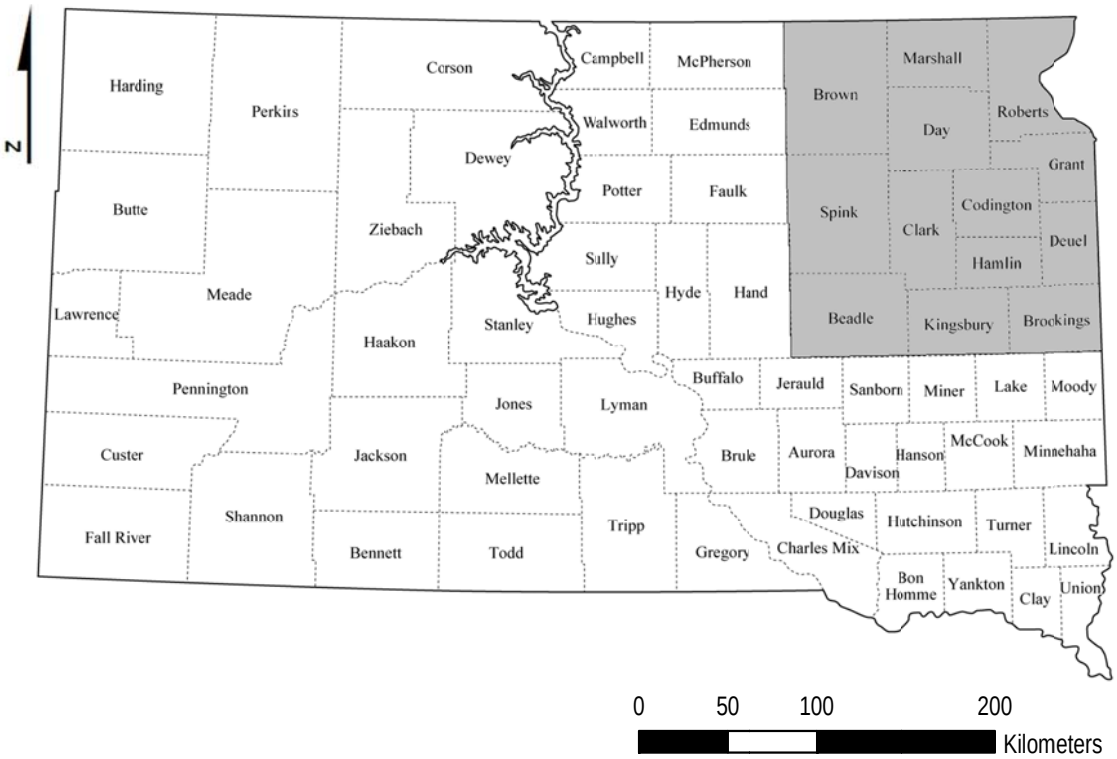

Figure 2-1. Study area counties of northeast South Dakota where colonial tree-nesting waterbird colonies (n=39) were monitored, 2008 – 2009

METHODS

Colony Selection

N. Drilling (unpub. data) identified 71 colonies that contained at least 1 study species nesting within my study area (Appendix A). I selected colonies based on species level of concern, rarity of species, number of species within a colony, and size of colony. Colonies that contained the 2 species of concern (BCNH and GBHE) were given preference. Species that occurred in the least amount of colonies within the study area were SNEG (n=4), BCNH (n=6), CAEG (n=7), and GREG (n=11). Therefore, colonies that included these 4 species were given second priority. Finally, larger mixed species colonies were given preference over smaller single species colonies (i.e. DCCO colonies). I selected 28 colonies in 2008 (Appendix B), and 25 colonies in 2009 (Appendix C) for study sites. I monitored 14 colonies in both 2008 and 2009 (Appendix D); therefore, 39 individual colony locations were monitored during this study (Figure 2-2).

Nest Selection

I initially photographed colonies in mid-April when the first study species arrived and established a nest within a selected colony. Nests were individually numbered on the photographs. I randomly selected 30 nests per species within a colony for monitoring throughout the breeding season. If a species in a colony had less than 30 nests, I monitored all of them. Selected nests were marked on pictograms and taken in the field to assure each selected nest was monitored during visits.

Nest Monitoring

Nesting colonial waterbirds are particularly vulnerable to human intrusion due to the large concentration of birds nesting in close proximity (Burger 1981, Rodgers and Smith 1995, Carney and Sydeman 1999). Colonial waterbirds will flush when approached too closely in an attempt to intimidate a predator or escape danger (Tremblay and Ellison 1979, Burger 1982). If disturbance is frequent, entire colony abandonment may result (Klein 1993, Nisbet 2000). As a result of human induced disturbance, reproductive success can ultimately be lowered. Nesting success can be directly lowered through abandonment of nests, eggs, or young, and by accidental crushing of eggs by adults when flushed off nests. Colony disturbance can also indirectly lower nest success through thermal stress, predation, cannibalism, and unnecessary stress resulting in excessive regurgitation of foods by young when adults are flushed from nests (Kury and Gochfeld 1975, Anderson and Keith 1980, Burger 1981, Parsons and Burger 1982, Fetterolf 1983, Carlson and Mclean 1996, Carney and Sydeman 1999).

Distance at which individuals in nesting colonies are disturbed depends on several factors, such as species composition, sensitivity to disturbance among species, timing of disturbance, and previous exposure to human activity (Burger and Gochfeld 1983, Erwin 1989). When approaching mixed colonies of tree-nesting waterbirds, Erwin (1989) and Rodgers and Smith (1995) found that most species flushed when humans were within 30 – 50 m, and suggested a setback distance of 100 – 150 m to minimize disturbance. A trade-off between accurate data and disturbance exists when monitoring nesting success of

colonial waterbirds. Daily colony visits result in greater accuracy of data, but nesting success may be lowered due to increased human disturbance. While visiting colonies less frequently may result in less accurate data, colony disturbance is minimized (Gillet et al. 1975, Robert and Ralph 1975, Conover and Miller 1978, Ellison and Cleary 1978, Gochfeld 1981, and Erwin and Custer 1982). Based on these findings, I visually inspected nests weekly from a distance of 100 – 150 m with 10x42 binoculars and a 20-60x82 spotting scope to mitigate observer disturbance (Siegel-Causey and Hunt 1981, Kelly et al. 1993, Baxter 1994).

I monitored nests from 15 April – 15 August in 2008 and 2009. Monitoring nests once a week is less precise than monitoring nests daily, but the costs of daily monitoring include decreased reproductive success as a result of increased disturbance, increased research expenses, and fewer colonies monitored (Burger 1982). I monitored nests once every 6 – 8 days and nest observations occurred throughout the day as N. Drilling (Pers. Commun.) found that time of day needs not be specific when monitoring nests of colonial tree-nesting waterbirds. The amount of time I spent observing nests varied due to colony size and species composition, but averaged 44.4 minutes ± 1.6.

I approached colonies located on islands within lakes and wetlands with a boat. During nest observation, I recorded the status of each selected nest (normal (intact), partly destroyed, or totally destroyed), presence or absence of adults and their activity (sitting, perched, or feeding young), and number of young per nest (Kelly et al. 1993). I estimated age based on size and feather development when young were initially detected. Initial chick

observation date for each nest was recorded and hatching date was determined through back calculating based on estimated age (McVaugh 1972, Butler 1992, Davis 1993, Telfair 1994, Naugle et al. 1996, Hatch and Weseloh 1999, Parsons and Master 2000, McCrimmon et al. 2001, Skagen 2001).

I defined a successful nest as having at least 1 hatchling. Hatched young for all species studied are altrical and remain within the nest until capable of flight. I monitored nests until their fate was determined as successful or unsuccessful. Successful nests were monitored throughout the nesting season until young had successfully fledged or perished. Fledging success was determined for each individual chick and for each nest, resulting in fledging rates of successfully hatched young and overall fledging success. Fledge success was defined as a nest fledging at least 1 chick. I determined fledge success for an individual by knowing the approximate age of all individuals in successfully hatched nests and age capable of flight for each species. Fledging stage was indicated when young were observed branching out away from nests and wing pumping.

Colony Censuses

I conducted a colony census during each visit. I counted total nests (active and non-active) and adults within each colony. I defined the edge of a colony as the outermost nest locations at each colony site (Naugle et al. 2000). Censuses provided a measure of colony size (number of active nests) and nest fluctuation throughout the breeding season.

Local Habitat Surveys

I measured habitat characteristics required for colonial tree-nesting waterbirds on wetlands of northeast South Dakota by conducting vegetation surveys within monitored colonies and at sites where no nesting occurred (Figure 2-2). I conducted habitat surveys at colonies after all nesting was completed, 15 August – 25 August in 2008 and 2009. Non-nesting sites were surveyed during the same time period.

Non-nesting Sites

Colony site selection is critical for successful nesting. Comparing habitat variables of nesting sites to sites where no nesting has occurred is important in understanding colonial tree-nesting waterbird nesting site selection. Drilling (2007) surveyed 1,025 sites for 46 species of colonial and semi-colonial nesting waterbird species across South Dakota. Of these sites, 69.5% did not contain any breeding waterbirds. However, 43% of these sites were deemed to have suitable waterbird nesting habitat. There were 38 sites in the study area identified by Drilling (2007) that contained flooded, dead trees where no nesting occurred.

Vegetation Surveys

I surveyed vegetation characteristics within 27 of the 39 active colonies monitored (Appendix E). Twelve sites were not surveyed due to access restrictions. I also surveyed 32 non-nesting sites within the study area (Appendix F). I systematically placed transects at 50 m intervals perpendicular to the longest axis of each colony and non-nesting site. I used

the point-centered quarter method (Cottam and Curtis 1956) to measure habitat variables at every 20 m. Within each quarter, at each point, I measured the distance to the nearest tree, identified to species and classified as live or dead. I measured total tree height by using a pole marked in one-tenth meter increments and for taller trees; I used a standard forestry clinometer. I calculated basal area at each site by measuring Diameter at Breast Height (DBH) with a standard metric forestry diameter tape. I measured ground coverage and herbaceous plant vegetation height along each transect at 10 m intervals by using a 1 m x 1 m modified Daubenmire frame and a standard metric tape measure, respectively. I estimated ocular percent cover of grass, cattail (*Typha spp.)*, forb, shrub, bare ground, and water (Bailey and Poulton 1968, Naugle et al. 2000). I recorded coverage percentage for each variable using the following Daubenmire cover classes: (0) = 0%, (1) >0-5%, (2) >5-25%, (3) >25-50%, (4) >50-75%, (5) >75-95% and (6) >95-100% (Daubenmire 1959). I also measured the area of colony and non-nesting sites by walking or boating around the edge of the entire colony with a Global Positioning System.

Landscape Habitat Surveys

I measured land use characteristics in 5 concentric rings expanding from the center of each colony and non-nesting site to assess how landscape attributes affect colony site selection and nest success (Gibbs and Kinkel 1997, Naugle et al. 2000). Buffer distances used were 400 m, 800 m, 1600 m, 3200m, and 6400 m. Land cover was obtained by using the 2001 National Land Cover Database (Homer et al. 2004). Land cover classes determined at each scale included the proportion of open water, deciduous forest, evergreen

forest, shrub, grassland/herbaceous, pasture/hay, cultivated crops, woody wetlands and emergent herbaceous wetlands.

Data Analyses

I analyzed nest success by using the apparent nest success estimator. I calculated nest success by dividing the total number of successful nests for each species at each colony by the total number of nests monitored for each species at each colony. I calculated fledge success by dividing the total number of nests that fledged at least 1 chick by the total number of nests monitored for each species at each colony. I calculated colony nest and fledge success by summing the total number of successful nests for all species monitored at a colony and dividing by the total number of nests monitored at a colony.

I determined factors affecting colony site selection by colonial tree-nesting waterbirds by performing logistic regression to analyze differences between used and unused sites (Hosmer and Lemeshow 1989). I developed 3 model sets for each species (local, landscape, and local and landscape) to predict colony site locations based from *a-priori* candidate models. I used multiple linear regression to analyze effects of local and landscape variables on nest success for each species. I based my models from the same set of *a priori* candidate models used for the colony site selection analysis. I examined correlations between independent variables by using the Pearson correlation matrix and excluded pairwise combinations that were highly correlated ($|r| > 0.50$) (Graham 2003). I based model selection from Akaike's Information Criterion corrected for small samples size (AIC_c) (Akaike 1969, Burnham and Anderson 2002). The best models were those that

yielded the lowest AIC_c value. I calculated the difference in candidate models from the top model (ΔAIC_c) and selected models with $\Delta AIC_c < 2.0$ as competing models based on the data (Burnham and Anderson 2002). I performed all statistical analyses and model development in SYSTAT® 12 (Systat 2007) and STATISTIX 8 (Statistix 2003).

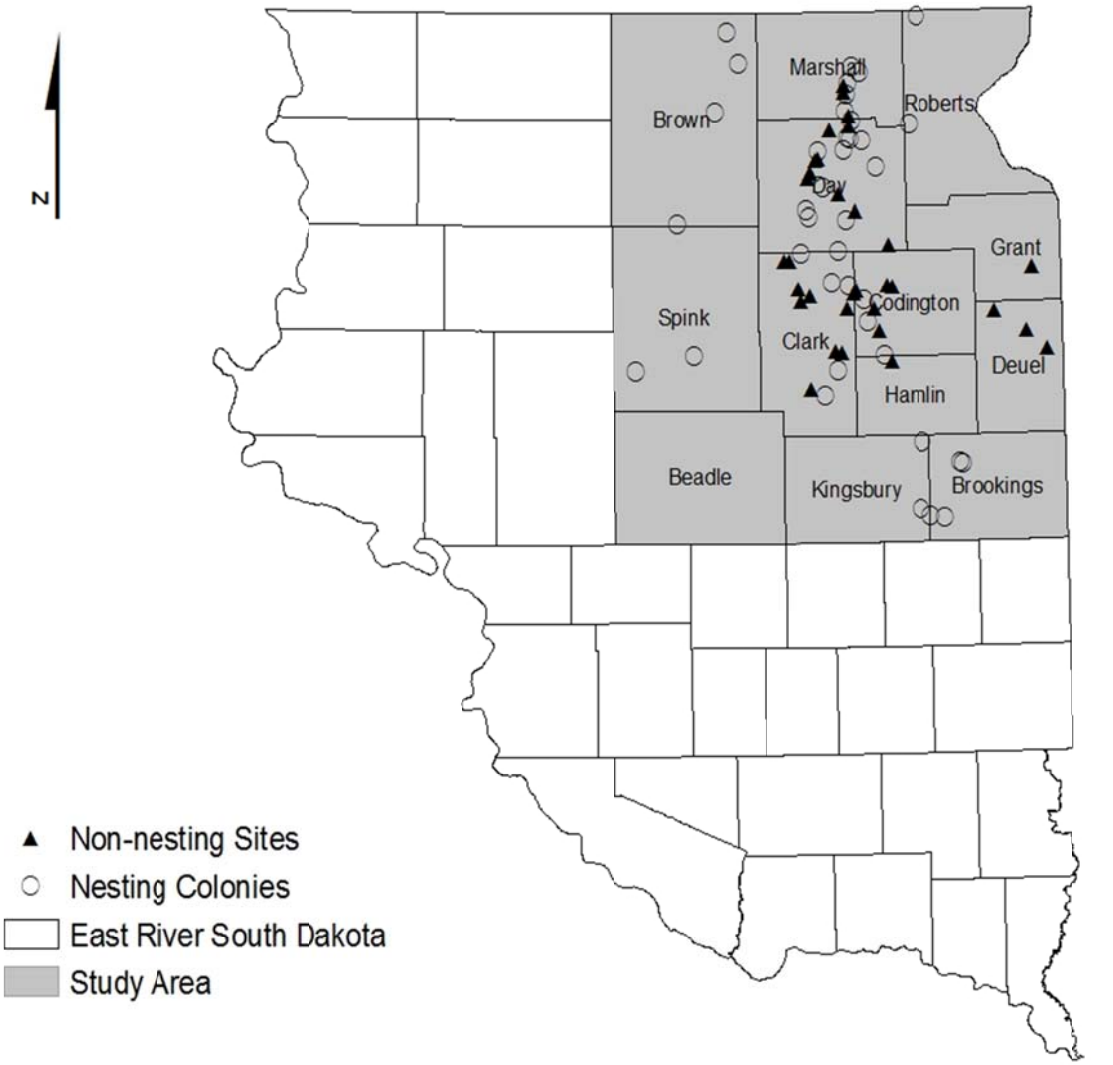

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Figure 2-2. Colonial tree-nesting waterbird colonies (n=39) and non-nesting site locations (n=32) in northeast South Dakota, 2008 – 2009.

CHAPTER 3

RESULTS

Nest Success

During this study, I monitored 2,635 total nests. There were 84 unknown nest success fates, resulting in 2,551 total nests for analysis (Table 3-1), 1,712 (67.1%) of them were successful. Nest success varied among species and years (Tables 3-2, 3-3). Cattle egrets exhibited significantly higher nesting success in 2008, while GBHE, GREG, and DCCO experienced significantly higher nesting success in 2009; BCNH and SNEG nest success was not significantly different between years (Table 3-4). Overall (2008 and 2009) apparent nest success was: BCNH (52.1%), GBHE (58.9%), CAEG (73.1%), GREG (61.5%), SNEG (83.6%), and DCCO (70.4%).

Hatching Dates and Brood Sizes

Earliest mean hatching date observed for 2008 and 2009 was 28-May and 29-May (GBHE), respectively, followed by DCCO (4-June and 29-May), GREG (16-June, and 9-June), SNEG (20-June, and 18-June), CAEG (22-June and 23-June), and BCNH (3-July and 3-July). Brood size was significantly higher in 2008 for CAEG, while GBHE, GREG, and DCCO experienced significantly higher brood sizes in 2009; BCNH and SNEG brood size was not significantly different between years (Table 3-5). Snowy egrets had the largest average brood size (2.94 ± 0.09) followed by CAEG (2.47 ± 0.07), GREG (2.44 ± 0.04), BCNH (2.36 ± 0.13), GBHE (2.13 ± 0.04), and DCCO (1.96 ± 0.02).

Table 3-1. Colonial tree-nesting waterbird species occurrence and nests monitored in selected colonies of northeast South Dakota, 2008 – 2009.

	BCNH	GBHE	CAEG	GREG	SNEG	DCCO
			2008			
Colonies	2	18	2	7	2	27
Nests	16	157	45	148	25	784
			2009			
Colonies	4	19	3	12	2	24
Nests	32	271	59	268	36	710
			Total			
Colonies	6	37	5	19	4	51
Nests	48	428	104	416	61	1,494

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Table 3-2. Colonial tree-nesting waterbird species nest and fledge success in selected colonies of northeast South Dakota, 2008.

Species	Nest Monitored	Successful Nests	Nest Success (%)	C.I. (95%)	Fledged Nests	Fledge Success (%)	C.I. (95%)
BCNH	16	8	50.0	24.7, 75.3	7	43.8	18.6, 68.8
GBHE	157	66	42.0	34.3, 49.8	23	14.6	9.1, 20.2
CAEG	45	40	88.9	79.6, 98.2	39	86.7	76.6, 96.7
GREG	148	69	46.6	38.5, 54.7	59	39.9	31.9, 47.8
SNEG	25	22	88.0	81.0, 94.9	21	87.5	69.3, 98.7
DCCO	784	493	62.9	59.5, 66.3	387	49.5	45.9, 52.9

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Table 3-3. Colonial tree-nesting waterbird species nest and fledge success in selected colonies of northeast South Dakota, 2009.

Species	Nest Monitored	Successful Nests	Nest Success (%)	C.I. (95%)	Fledged Nests	Fledge Success (%)	C.I. (95%)
BCNH	32	17	53.2	35.6, 70.7	16	50.0	32.4, 67.6
GBHE	271	186	68.6	63.1, 74.2	130	48.3	42.0, 53.9
CAEG	59	36	61.0	48.5, 73.6	33	55.9	43.2, 68.7
GREG	268	187	69.8	64.3, 75.3	152	56.7	50.8, 62.7
SNEG	36	29	80.6	67.5, 93.7	28	77.8	64.0, 91.6
DCCO	710	559	78.7	75.7, 81.7	422	59.4	55.8, 63.1

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Table 3-4. Chi-square comparison of colonial tree-nesting waterbird species nest success between years 2008 and 2009, in northeast South Dakota. Species with significantly different ($p<0.05$) nest success are denoted by an *.

Species	Successful Nests 2008	Unsuccessful Nests 2008	Successful Nests 2009	Unsuccessful Nests 2009	X^2
BCNH	8	8	17	15	0.8381
*GBHE	66	91	186	85	<0.0001
*CAEG	40	5	36	23	0.0015
*GREG	69	79	187	81	<0.0001
SNEG	22	3	29	7	0.4399
*DCCO	493	291	559	151	<0.0001

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Table 3-5. Two-sample t-test comparison of colonial tree-nesting waterbird brood sizes in selected colonies of northeast South Dakota, 2008 – 2009. Species with significantly different (p<0.05) brood sizes are denoted by an *.

Species	n 2008	n 2009	Brood Size (Mean ± SE) 2008	Brood Size (Mean ± SE) 2009	Brood Size (Mean ± SE) 2008 & 2009	P	Range
BCNH	8	17	2.38 ± 0.18	2.35 ± 0.17	2.36 ± 0.13	0.9377	1 – 3
*GBHE	66	186	1.91 ± 0.07	2.21 ± 0.05	2.13 ± 0.04	0.0025	1 – 5
*CAEG	40	36	2.60 ± 0.09	2.33 ± 0.10	2.47 ± 0.07	0.0434	1 – 4
*GREG	69	187	2.26 ± 0.08	2.51 ± 0.05	2.44 ± 0.04	0.0133	1 – 4
SNEG	22	29	2.86 ± 0.15	3.00 ± 0.11	2.94 ± 0.09	0.4604	1 – 4
*DCCO	493	559	1.79 ± 0.03	2.11 ± 0.03	1.96 ± 0.02	<0.0001	1 – 4

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant, n = number of nests that successfully hatched young.

Fledge Success

I determined fledging success for all nests monitored in 2008 (Table 3-2) and 2009 (Table 3-3) with the exception of 5 nests, DCCO (2), GBHE (2) and SNEG (1), which were unknown due to visual obstruction. Fledge success was significantly higher in 2008 for CAEG, while GBHE, GREG, and DCCO experienced significantly higher fledging success in 2009; BCNH and SNEG fledge success was not significantly different between years (Table 3-6). Overall fledge success for all nests monitored was highest for SNEG (81.7%), followed by CAEG (69.2%), DCCO (54.2%), GREG (50.7%), BCNH (47.9%), and GBHE (35.9%). Of the 1,712 nest that successfully hatched young, fledging fate was determined on 1,707, of which 1,317 (77.2%) successfully fledged at least 1 chick. Combined (2008 and 2009) fledge success for successful hatching nests only was highest for SNEG (98.0%)

followed by CAEG (94.7%), BCNH (92.0%), GREG (82.4%), DCCO (77.5%), and GBHE (61.2%). Mean number of young fledged per nest was highest for SNEG (2.3 ± 0.16), followed by CAEG (1.5 ± 0.11), GREG (1.2 ± 0.06), BCNH (1.1 ± 0.18), DCCO (0.9 ± 0.03), and GBHE (0.7 ± 0.05) (Table 3-7). Mean fledging date (2008 and 2009) was earliest for SNEG (20-July and 18-July) followed by DCCO (22-July and 22-July), CAEG (23-July and 30-July), GBHE (25-July and 24-July), GREG (5-August and 3-August), and BCNH (5-August and 8-August).

Table 3-6. Chi-square comparison of colonial tree-nesting waterbird species fledge success between years, 2008 and 2009, in northeast South Dakota. Species with significantly different ($p<0.05$) fledge success are denoted by an *.

Species	**Successful Nests 2008**	**Unsuccessful Nests 2008**	**Successful Nests 2009**	**Unsuccessful Nests 2009**	X^2
BCNH	7	9	16	16	0.6828
*GBHE	23	134	130	141	<0.0001
*CAEG	39	6	33	26	0.0008
*GREG	59	89	152	116	0.0010
SNEG	21	4	28	8	0.5477
*DCCO	387	397	422	288	<0.0001

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Table 3-7. Colonial tree-nesting waterbird species mean fledge success in selected colonies of northeast South Dakota, 2008 – 2009.

Species	Mean (±SE) Fledged/Nest	Mean (±SE) Fledged/Successful Nest	Mean (±SE) Fledged/Successfully Fledged Nest
BCNH	1.1 ± 0.18	2.1 ± 0.17	2.3 ± 0.13
GBHE	0.7 ± 0.05	1.2 ± 0.07	2.0 ± 0.06
CAEG	1.5 ± 0.11	2.1 ± 0.09	2.2 ± 0.08
GREG	1.2 ± 0.06	1.9 ± 0.07	2.3 ± 0.05
SNEG	2.3 ± 0.16	2.8 ± 0.11	2.8 ± 0.09
DCCO	0.9 ± 0.03	1.4 ± 0.03	1.7 ± 0.02

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Colony Success

I monitored 53 colonies during this study, 14 of which were monitored in both 2008 and 2009 (Appendix D). Mean colony nesting and fledging success was 65.7% and 48.9% respectively (Appendices G-J). Colony nesting success was significantly different ($p<0.05$) (Chi-square test) between years in 6 of the 14 colonies (Table 3-8), while colony fledging success was different between 4 colonies (Table 3-9).

Black-crowned night herons nested in colonies that contained at least 3 other colonial tree-nesting waterbird species (Appendices B and C). All colonies containing BCNHs were located on islands except 1. Black-crowned night herons comprised a mean of 2.8% of the total number of nests present in colonies in which they nested. Great Blue Herons nested in 37 of the 53 colonies monitored (Figure 3-1). Two colonies contained

only GBHEs, while other colonies comprised up to 3 other species. Of the 37 GBHE colonies, 21 were comprised of only GBHE and DCCO. Within these colonies, GBHE comprised a mean of 7.8% of the total nests. Overall, GBHE comprised 13.6% of nests in colonies and 21.3% in colonies that contained species other than only DCCO. Nest success (51.7%) was not significantly different ($p=0.10$, $\alpha = 0.05$), (Chi-square test) in colonies where GBHEs nested only with DCCOs compared to their overall nest success (58.2%). However, nest success was significantly different ($p=0.01$) when compared to sites where GBHE nested with species other than only DCCOs (63.9%).

Great Egrets nested in colonies that contained 3 to 5 colonial tree-nesting waterbird species while CAEG and SNEG nested with 4 to 5 study species (Appendices B and C). Double-crested cormorants nested in 51 colonies, 12 of which were solely DCCO colonies and 20 contained only DCCO and GBHE. Nineteen other colonies contained 3 to 5 species of colonial tree-nesting waterbirds.

Table 3-8. Chi-square comparison of colonial tree-nesting waterbird colony nest success for colonies (n=14) monitored in 2008 and 2009 in northeast South Dakota. Colonies that were significantly different ($p < 0.05$) are denoted by an *.

Site	**Success (%) 2008**	**Success (%) 2009**	X^2
Blythe Slough	70.71	76.80	0.3012
Brunick WPA	79.31	88.00	0.3929
Crow Creek Ditch @ 122 St.*	19.15	92.68	0.0000
Drywood Lake*	8.89	62.22	0.0000
East Hecla GPA	75.86	81.48	0.3751
Hazelden Springs GPA	49.12	60.53	0.1902
Holmquist Slough	90.63	90.32	0.9674
Kettle Lake*	28.57	49.15	0.0164
Krause Farm GPA (East)	79.41	83.87	0.6435
Little Cottonwood Lake GPA*	47.37	69.70	0.0399
Oakwood Lake -1	88.79	82.88	0.2123
Opitz Lake*	26.47	6.67	0.0361
Twin Lake (East)*	27.03	68.57	0.0004
Wolf Slough GPA	66.67	77.78	0.3020

Table 3-9. Chi-square comparison of colonial tree-nesting waterbird colony fledge success for colonies (n=14) monitored in 2008 and 2009 in northeast South Dakota. Colonies that were significantly different ($p < 0.05$) are denoted by an *.

Site	**Success (%) 2008**	**Success (%) 2009**	X^2
Blythe Slough	63.64	70.40	0.2835
Brunick WPA	55.17	40.00	0.2659
Crow Creek Ditch @ 122 St.*	12.77	85.71	0.0000
Drywood Lake*	0.00	46.67	0.0000
East Hecla GPA	55.17	69.14	0.0626
Hazelden Springs GPA	42.11	38.16	0.6454
Holmquist Slough	62.50	67.74	0.6626
Kettle Lake*	14.29	33.90	0.0086
Krause Farm GPA (East)	73.53	61.29	0.2919
Little Cottonwood Lake GPA	38.60	51.52	0.2333
Oakwood Lake -1	81.31	74.77	0.2445
Opitz Lake	0.00	0.00	0.9305
Twin Lake (East)*	0.00	34.29	0.0001
Wolf Slough GPA	60.61	58.33	0.8477

Species Occurrence and Abundance

Number of nests monitored for each species was not equal (Figure 3-1), but they were representative of the proportion of nests that occurred by species within the study area. Double-crested cormorants occurred in the most colonies monitored (n=51), while SNEG occurred in the least (n=4) (Figure 3-2).

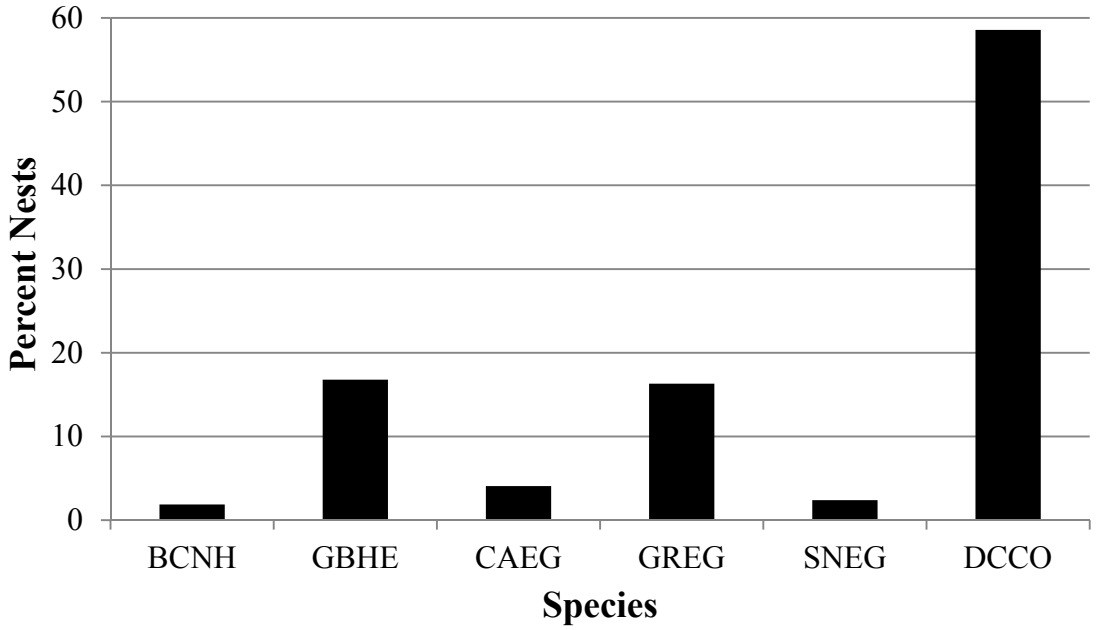

Figure 3-1. Relative abundance of nest monitored in colonies (n=53) of colonial tree-nesting waterbird species in northeast South Dakota, 2008 – 2009.

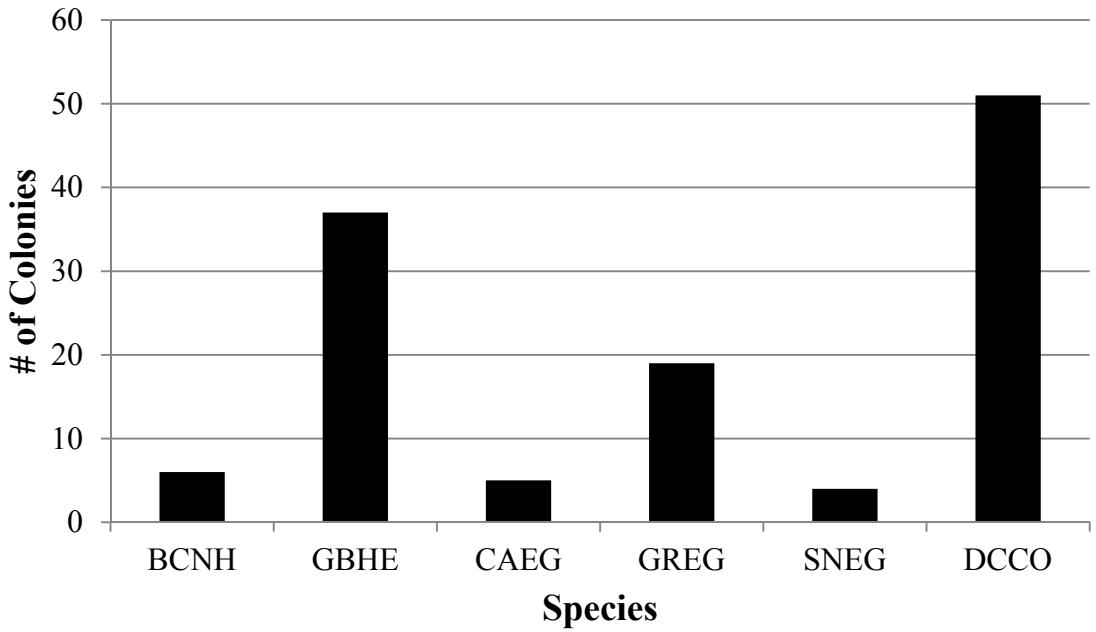

Figure 3-2. Frequency of occurrence in colonies (n=53) of colonial tree-nesting waterbird species monitored in northeast South Dakota, 2008 – 2009.

Nest Failure

If I did not detect any young in a nest, it was classified as unsuccessful. There were 839 (32.9%) unsuccessful nests. Sources of failure included: nest abandonment, predation, death of adults, tree structure failure, nest structure failure, and nest takeover. The highest source of nesting failure was attributed to nest abandonment. Nest abandonment ranged from 34.7% of total failures in BCNH to 64.3% in CAEG, with a mean of 47.6% for all species combined (Figure 3-3). Nest structure was the second highest leading cause of nest failure, which accounted for a mean of 30.4% for all species. Great Blue Herons had the highest rate of nest takeover (37.3%), solely attributed to DCCOs.

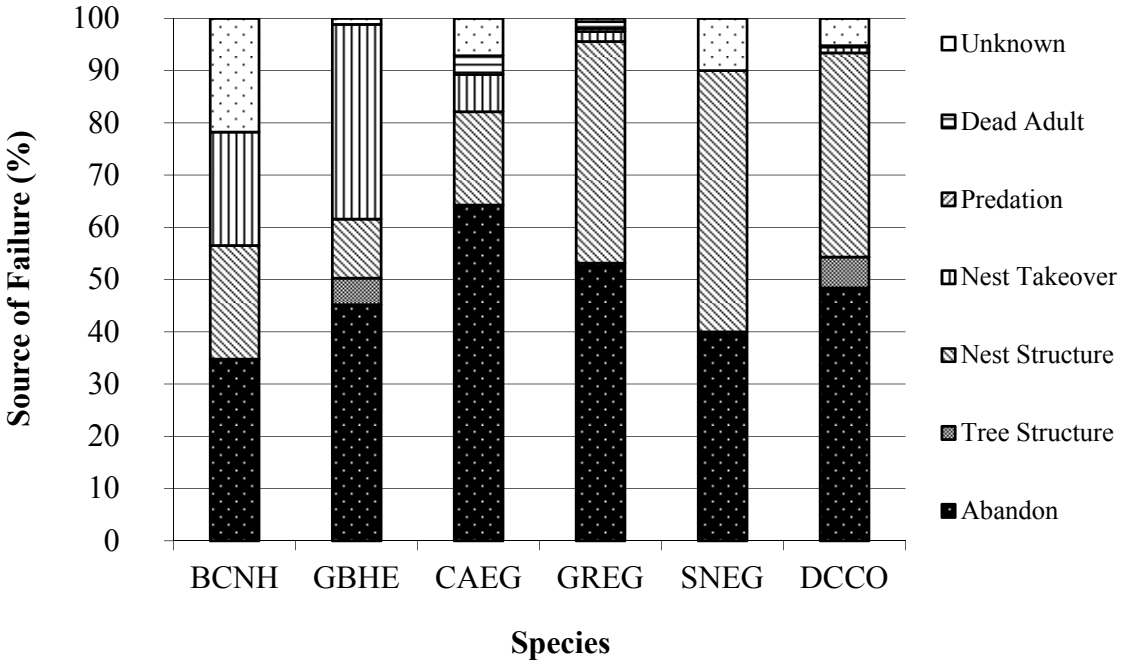

Figure 3-3. Colonial tree-nesting waterbird species nesting failure sources in northeast South Dakota, 2008 – 2009.

Fledge Failure

I monitored successful hatching nests until young either perished or fledged. Of the total nests monitored, 1,234 (48.4%) did not fledge any young while successful nests had a fledging rate of 77.2%. Successful nests that did not fledge any young were categorized based on the cause of failure. Sources of failure included: nest abandonment, tree structure failure, nest structure failure, predation, nest takeover, death of adults, and death of young. The highest sources of fledge failure were primarily attributed to nest structure failure and young dying within the nest (Figure 3-4).

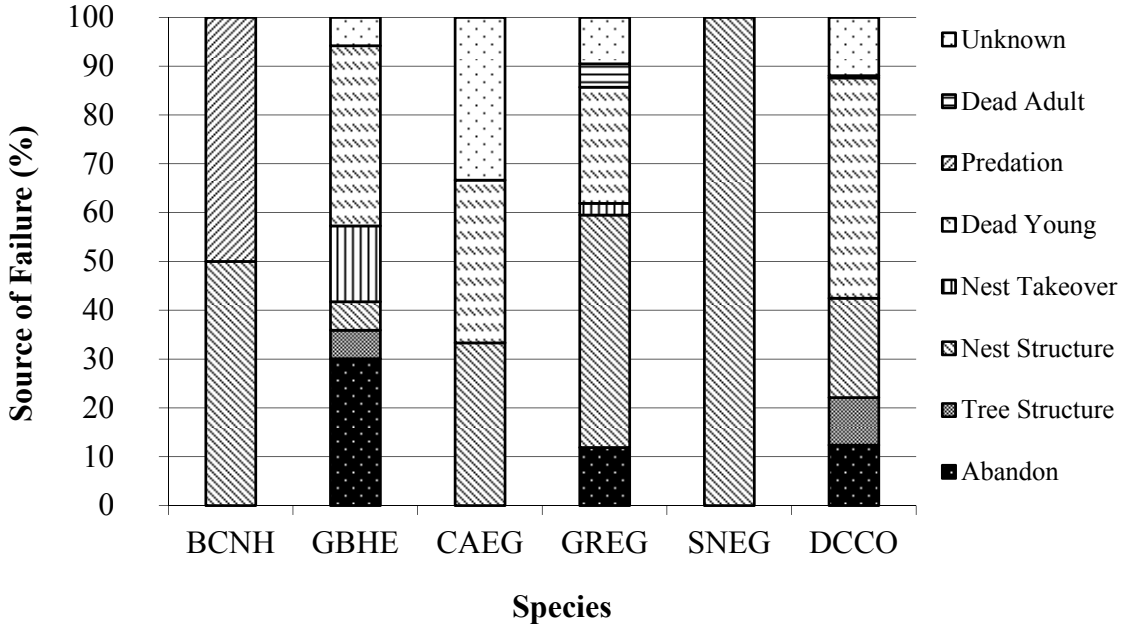

Figure 3-4. Colonial tree-nesting waterbird species fledging failure sources in northeast South Dakota, 2008 – 2009.

Colony Site Selection

I created 3 model sets a multi-level scales for all 6 colonial tree-nesting waterbird study species. Predictive models for colony sites locations differed for all species. However, all best-fit models describing colony site locations for all species included habitat characteristics at both the local and landscape levels. Local and landscape model variables and corresponding codes are found in appendices K and L, respectively.

Black-crowned Night Heron

Black-crowned night heron colony site locations were positively associated with bare ground, shrubs, and eastern redcedar (*Juniperus virginiana*) within colonies, and

percent open water and grass within 400 m of colonies. Colony locations were negatively associated with grass, forbs, and cattails within colonies. The best model developed predicting BCNH colony site locations contained variables from the local and landscape spatial scales (Table 3-10). Averages of measured variables included in models are listed in Table 3-11.

Table 3-10. Colony site occurrence models for Black-Crowned Night Herons in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**Wi**
Local & Landscape	+ BareGr + CedarDen – Grass + Open_400 + Grass_400	12.92	0.00	0.960
Landscape	+ Open_400 + Grass_400	20.37	7.45	0.023
Landscape	+ Open_400 + Grass_800	21.82	8.90	0.011
Local	+ BareGr + CedarDen + Shrub – Grass	25.51	12.59	0.002
Local	+ BareGr + CedarDen + Shrub	26.45	13.53	0.001
Local	+ BareGr + Shrub – Grass	26.77	13.85	<0.001
Local	+ Shrub – Grass	26.65	13.73	<0.001
Local	+ BareGr + CedarDen + Shrub – Grass – Forb	27.45	14.53	<0.001
Local	+ BareGr + CedarDen + Shrub – Grass – Cattail	27.48	14.56	<0.001

Table 3-11. Black-crowned Night Heron colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	**Mean (±SE)**	**Min.**	**Max**	**N**
% BareGr	44.3 ± 22.0	0.6	97.5	5
% Cattail	0.0	0.0	0.0	5
CedarDen (Trees/ha)	278 ± 173.8	0	807	5
% Forb	18.2 ± 12.5	0.0	63.6	5
% Grass	0.0	0.0	0.0	5
HVHt* (cm)	34.0 ± 21.6	0.0	105.5	5
% Shrub	17.0 ± 10.5	0.0	47.5	5
% Grass_400	6.6 ± 3.4	0.0	17.7	5
% Grass_800	23.5 ± 6.9	12.7	50.1	5
% HerbWet_6400*	7.1 ± 1.1	4.7	10.7	5
% Open_400	90.4 ± 3.9	76.5	99.3	5
% Open_3200*	21.2 ± 2.6	12.9	29.0	5
% TotWet_3200*	28.6 ± 3.0	18.5	36.1	5

* Denotes variables included in nest success models, but not colony site models.

Great Blue Heron

Great blue heron colony site locations were positively associated with green ash (*Fraxinus pennsylvanica*) within colonies, colony area, and herbaceous wetlands at 800 m, 1600 m, and 6400 m. Colony sites were negatively associated with grass within the colony and at 400 m, and developed area within 400 m. Nine of the 10 competitive models (ΔAICc $\leq$ 2.0), included both local and landscape variables (Table 3-12). Averages of measured variables included in models are listed in Table 3-13.

Table 3-12. Colony site occurrence models for Great Blue Herons in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	Model	AICc	ΔAICc	W_i
Local & Landscape	– Grass + GrnAshDen – Grass_400 – Dev_400 +HerbWet_6400	62.30	0.00	0.151
Local	– Grass + GrnAshDen + ColArea	62.61	0.31	0.129
Local & Landscape	– Grass + GrnAshDen – Grass_400 – Dev_400 + HerbWet_6400 + ColArea	62.92	0.62	0.111
Local & Landscape	– Grass + GrnAshDen – Grass_400 + HerbWet_6400	62.97	0.67	0.108
Local & Landscape	– Grass + GrnAshDen – Grass_400 – Dev_400 + HerbWet_800	63.14	0.84	0.099
Local & Landscape	– Grass + GrnAshDen + ColArea – Dev_400	63.22	0.92	0.095
Local & Landscape	– Grass + GrnAshDen + ColArea – Grass_400 – Dev_400	63.38	1.08	0.088
Local & Landscape	– Grass + GrnAshDen + ColArea – Grass_400	63.46	1.16	0.084
Local & Landscape	– Grass + GrnAshDen – Grass_400 – Dev_400	63.69	1.39	0.075
Local & Landscape	– Grass + GrnAshDen – Grass – Dev_400 + HerbWet_1600	64.14	1.84	0.060
Landscape	– Grass_400 – Dev_400	85.14	22.84	<0.001
Landscape	– Grass_400 – Dev_400 + HerbWet_800	86.89	24.59	<0.001

Table 3-13. Great Blue Heron colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	Mean (±SE)	Min.	Max	N
% BareGr*	12.1 ± 6.0	0.0	97.5	22
ColArea (Ha)	2.0 ± 0.8	0.1	15	22
% DCCO*	75.2 ± 5.5	0.0	99.2	37
% Forb*	10.3 ± 3.3	0.0	49.2	22
% Grass	4.1 ± 2.3	0.0	34.2	22
GrnAshDen (Trees/ha)	95 ± 28.3	0	390	22
% Water*	55.9 ± 9.1	0.0	97.5	22
% Dev_400	2.0 ± 0.7	0.0	15.6	27
% Dev_6400*	3.5 ± 0.2	1.6	5.0	27
% Grass_400	10.8 ± 2.2	0.0	38.9	27
% Grass_800*	19.1 ± 2.6	0.0	49.0	27
% Grass_6400*	32.3 ± 3.6	6.4	73.2	27
% HerbWet_400*	18.4 ± 4.6	0.0	77.4	27
% HerbWet_800	14.9 ± 3.2	0.0	53.1	27
% HerbWet_1600	10.7 ± 1.9	1.3	34.7	27
% HerbWet_6400	8.8 ± 0.9	1.4	21.7	27

* Denotes variables included in nest success models, but not colony site models.

Cattle Egret

Cattle egret colony site locations were positively associated with bare ground, eastern redcedar, and dead trees within colonies, grass at 400 m, 1600 m, and 3200 m, and open water and total wetland area at 400 m surrounding colonies. Cattle egret colony locations were negatively associated with grass within colonies. I developed 2 competitive models predicting CAEG colony site locations (Table 3-14). Both competitive models contained local and landscape variables. Averages of measured variables included in models are listed in Table 3-15.

Table 3-14. Colony site occurrence models for Cattle Egrets in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc $\leq$ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ BareGr + CedarDen + Grass_1600	8.36	0.00	0.494
Local & Landscape	+ BareGr + CedarDen + Grass_3200	8.36	0.00	0.494
Local	+ BareGr + CedarDen	16.99	8.63	0.007
Local	+ BareGr + CedarDen – Grass	18.70	10.34	0.003
Local	+ BareGr + CedarDen+ DeadTree	18.77	10.41	0.003
Landscape	+ Open_400	23.90	15.54	<0.001
Landscape	+ Open_400 + Grass_400	24.36	16.00	<0.001
Landscape	+ TotWet_400	25.38	17.02	<0.001

Table 3-15. Cattle Egret colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	**Mean (±SE)**	**Min.**	**Max**	**N**
% BareGr	65 ± 32.5	0.0	97.5	3
CedarDen (Trees/ha)	463 ± 240.4	0	807	3
% DeadTree	72.2 ± 23.7	25.0	100	3
% Grass	0.0	0.0	0.0	3
% Water*	32.5 ± 32.5	0.0	97.5	3
% Grass_400	11.8 ± 3.4	5.9	17.8	3
% Grass_1600	37.8 ± 11.1	28.0	60.0	3
% Grass_3200	38.9 ± 8.1	29.4	54.9	3
% Open_400	83.0 ± 3.4	76.6	88.4	3
% Open_800*	56.5 ± 6.6	43.4	64.1	3
% Open_1600*	32.0 ± 4.3	23.4	36.2	3
% Open_3200*	23.2 ± 5.2	12.9	29.0	3
% TotWet_400	85.8 ± 1.9	82.2	88.4	3
% TotWet_800*	60.0 ± 6.1	47.4	66.1	3

* Denotes variables included in nest success models, but not colony site models.

Great Egret

Great egret colony site locations were positively associated with shrubs, bare ground, and water within colonies, open water surrounding colonies at 400 m, and developed area within 6400 m of colonies. Colony locations were negatively associated with the amount of developed area and grass within 400 m of colonies, and cropland within 3200 m and 6400 m of colony locations. The best model developed to predict GREG colony site locations contained variables from the local and landscape spatial scales (Table 3-16). Averages of measured variables included in models are listed in Table 3-17.

Table 3-16. Colony site occurrence models for Great Egrets in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ Shrub + Open_400 + BareGr + Water	43.39	0.00	0.892
Local	+ BareGr + Shrub	49.10	5.71	0.051
Local	+ BareGr + Shrub + Water	50.53	7.14	0.025
Landscape	– Dev_400 + Open_400	53.00	9.61	0.007
Landscape	+ Open_400 + Dev_6400	53.83	10.44	0.005
Landscape	– Dev_400 + Open_400 + Dev_6400	54.15	10.76	0.004
Landscape	+ Open_400 – Grass_400	54.16	10.77	0.004
Landscape	+ Open_400 – Crop_3200	54.20	10.81	0.004
Landscape	+ Open_400 – Crop_6400	54.24	10.85	0.004
Landscape	– Dev_400 + Open_400 – Grass_400	54.76	11.37	0.003

Table 3-17. Great Egret colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	**Mean (±SE)**	**Min.**	**Max**	**N**
% BareGr	27.3 ± 10.7	0.0	97.5	13
% Grass*	5.5 ± 3.5	0.0	34.2	13
% Shrub	8.7 ± 4.7	0.0	47.5	13
% Water	36.0 ± 12.0	0.0	97.5	13
% Crop_3200	26.6 ± 5.2	1.7	70.7	13
% Crop_6400	31.3 ± 5.2	5.6	66.4	13
% Dev_400	1.5 ± 0.6	0.0	5.9	13
% Dev_6400	3.2 ± 0.4	0.7	4.5	13
% Grass_400	8.4 ± 3.1	0.0	38.9	13
% Grass_6400*	40.0 ± 4.8	12.7	73.2	13
% Open_400	79.2 ± 5.4	42.7	99.4	13
% WoodWet_6400*	.008 ± .002	0.0	0.02	13

* Denotes variables included in nest success models, but not colony site models.

Snowy Egret

Snowy egret colony site locations were positively associated with bare ground, eastern redcedar, and dead trees within colonies, and open water, grass, and total wetland area surrounding colonies at 400 m. I developed 2 competitive models predicting SNEG colony site locations (Table 3-18). The best model contained local and landscape variables while the second competitive model contained only 1 local variable. Averages of measured variables included in models are listed in Table 3-19.

Table 3-18. Colony site occurrence models for Snowy Egrets in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc $\leq$ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ BareGr + Open_400	6.18	0.00	0.475
Local	+ BareGr	7.87	1.69	0.204
Local	+ BareGr + CedarDen + DeadTree	8.36	2.18	0.160
Local	+ BareGr + CedarDen	8.95	2.18	0.160
Landscape	+ Open_400	18.05	11.87	0.001
Landscape	+ Open_400 + Grass_400	19.45	13.27	<0.001
Landscape	+ TotWet_400	19.37	13.19	<0.001

Table 3-19. Snowy Egret colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	**Mean (±SE)**	**Min.**	**Max**	**N**
% BareGr	97.5 ± 0.0	97.5	97.5	2
CedarDen (Trees/ha)	404 ± 403.5	0	807	2
% DeadTree	58.4 ± 33.4	25.0	91.7	2
% Grass_400	8.8 ± 2.9	5.9	11.6	2
% Open_400	86.2 ± 2.3	83.9	88.4	2
% TotWet_400	87.6 ± 0.8	86.8	88.4	2

Double-crested Cormorant

Double-crested cormorant colony site locations were positively associated with bare ground within colonies, open water and total wetland area within 400 m, and total wetland area within 6400 m of colonies. Colony locations were negatively associated with herbaceous vegetation height, percent grass, and cottonwood (*Populus deltoides*) density within colonies, and grass within 400 m of colony locations. I developed 2 competitive models predicting DCCO colony site locations (Table 3-20). Both competitive models contained local and landscape variables. Averages of measured variables included in models are listed in Table 3-21.

Table 3-20. Colony site occurrence models for Double-crested Cormorants in northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ Open_400 + BareGr – Grass_400	61.77	0.00	0.493
Local & Landscape	+ Open_400 + BareGr – CotDen	61.85	0.08	0.474
Local	+ BareGr – Grass – HVHt – CotDen	67.20	5.43	0.033
Landscape	+ Open_400 – Grass_400	88.59	26.82	<0.001
Landscape	+ TotWet_400	89.33	27.56	<0.001
Landscape	– Grass_400 + TotWet_6400	90.04	28.27	<0.001

Table 3-21. Double-crested Cormorant colony site variable means (±SE) and ranges for nesting locations in northeast South Dakota, 2008 – 2009.

Variable	**Mean (±SE)**	**Min.**	**Max**	**N**
% BareGr	17.4 ± 6.7	0.0	97.5	26
CotDen (Trees/ha)	90.0 ± 25.3	0	554	26
LfHT (cm)	35.6 ± 10.3	0.0	197.3	26
MTHt (m)	7.9 ± 0.5	4.6	13.8	26
% Dev_6400*	3.5 ± 0.1	1.6	5.0	37
% Grass_400	14.3 ± 2.7	0.0	42.3	37
% HerbWet_6400*	8.4 ± 0.7	1.6	21.7	37
% Open_400	61.6 ± 5.6	0.0	95.4	37
% TotWet_400	72.6 ± 4.4	6.0	98.9	37
% TotWet_6400	24.4 ± 1.8	9.7	51.6	37

* Denotes variables included in nest success models, but not colony site models.

Nest Success Predictive Models

I created 3 model sets at multi-level scales predicting nesting success for all colonial tree-nesting waterbird study species, with the exception of snowy egrets. Snowy egrets were only observed nesting in 2 colonies, and therefore I was unable to create any nest success predictive models. Model sets predicting nest success varied among species. Local variables were the best predictors for BCNH and GREG nest success. Landscape variables were best at predicting CAEG nest success and a combination of local and landscape variables were the best at predicting nest success for GBHEs and DCCOs.

Black-crowned Night Heron

Black-crowned night heron nesting success models were positively associated with bare ground, open water and total wetland area within 3200 m and herbaceous wetlands within 6400 m of colonies. Nesting success of BCNHs was negatively associated with forbs, shrubs, and herbaceous vegetation height within colonies. Four of the top 6 competitive models developed contained only local variables (Table 3-22). Averages of measured variables included in models are listed in Table 3-11.

Table 3-22. Nest success predictive models for Black-crowned Night Herons nesting in colonies of northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	Model	AICc	ΔAICc	W_i
Local	+ BareGr	72.58	0.00	0.217
Landscape	+ Open_3200	73.33	0.75	0.149
Local	– Shrub	73.65	1.07	0.127
Landscape	+ TotWet_3200	73.66	1.08	0.126
Local	– HVHt	74.19	1.61	0.097
Local	– Forb	74.31	1.73	0.091
Landscape	+ HerbWet_6400	74.82	2.24	0.071
Local & Landscape	– HVHt + Open_3200	75.09	2.51	0.062
Local & Landscape	– Forb + Open_3200	75.18	2.60	0.059

Great Blue Heron

Great blue heron nesting success models were positively associated with bare ground within colonies, herbaceous wetlands within 400 m and 1600 m, grass within 800 m and 6400 m, and developed area within 6400 m. Nesting success of GBHEs was negatively associated with forbs, grass, water, and percentage of DCCO within colonies (Figure 3-5). The top 4 competitive models developed contained both local and landscape level variables (Table 3-23). Averages of measured variables included in models are listed in Table 3-13.

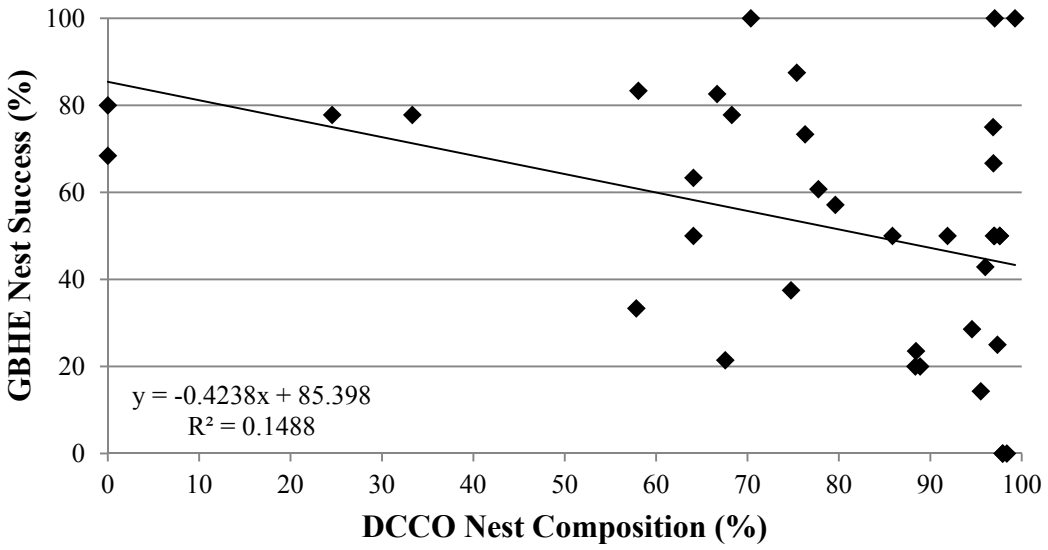

Figure 3-5. Great blue heron (GBHE) nest success vs. colony percentage of double-crested cormorant (DCCO) nests occurring in GBHE colonies (n=37) of northeast South Dakota, 2008 – 2009.

Table 3-23. Nest success predictive models for Great Blue Herons nesting in colonies of northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc ≤ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ BareGr – % DCCO + HerbWet_1600	508.80	0.00	0.383
Local & Landscape	+ BareGr – Grass – % DCCO + HerbWet_1600	509.99	1.19	0.212
Local & Landscape	+ BareGr – % DCCO + HerbWet_1600 + Dev_6400	510.18	1.38	0.192
Local & Landscape	+ BareGr – % DCCO + HerbWet_400 + Dev_6400	510.22	1.42	0.189
Local	+ BareGr – Grass – % DCCO	515.63	6.83	0.013
Local	– Forb – Water – % DCCO	517.01	8.21	0.006
Local	+ BareGr – Forb – % DCCO	517.41	8.61	0.005
Landscape	+ HerbWet_400 + Grass_6400 + Dev_6400	603.62	94.82	<0.001
Landscape	+ HerbWet_1600 + Grass_800 + Dev_6400	604.72	95.92	<0.001

Cattle Egret

Cattle egret nesting success models were positively associated with bare ground, open water within 800 m, 1600 m, and 3200 m, and total wetland area within 800 m. Nesting success of CAEGs was negatively associated with water within colonies. Four of the top 6 competitive models contained only landscape variables; while only local variables comprised the 2 other best models (Table 3-24). Averages of measured variables included in models are listed in Table 3-15.

Table 3-24. Nest success predictive models for Cattle Egrets nesting in colonies of northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc $\leq$ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Landscape	+ TotWet_800	91.90	0.00	0.175
Landscape	+ Open_1600	91.99	.09	0.167
Local	+ BareGr	92.02	.12	0.165
Local	– Water	92.02	.12	0.165
Landscape	+ Open_3200	92.19	.29	0.151
Landscape	+ Open_800	92.68	.78	0.118
Local & Landscape	+ BareGr + TotWet_800	94.07	2.17	0.059

Great Egret

Great egret nesting success models were positively associated with woody wetlands within 6400 m. Nesting success of GREGs was negatively associated with grass and shrubs within colonies, and grass and developed area within 6400 m. The best model developed contained only 2 local variables (Table 3-25). Averages of measured variables included in models are listed in Table 3-17.

Table 3-25. Nest success predictive models for Great Egrets nesting in colonies of northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc $\leq$ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local	– Grass – Shrub	442.30	0.00	0.635
Local & Landscape	– Grass_6400 – Shrub – Grass	444.15	1.85	0.252
Local & Landscape	+ WoodWet_6400 – Grass_6400 – Shrub – Grass – Dev_6400	445.76	3.46	0.113
Landscape	+ WoodWet_6400 – Grass_6400 – Dev_6400	494.66	52.36	<0.001

Double-crested Cormorant

Double-crested cormorant nesting success models were positively associated with bare ground within colonies, open water within 400 m, and herbaceous wetlands and developed area within 6400 m. Nesting success of DCCOs was negatively associated with herbaceous vegetation height within colonies. The best model developed contained both local and landscape variables (Table 3-26). Averages of measured variables included in models are listed in Table 3-21.

Table 3-26. Nest success predictive models for Double-crested Cormorants nesting in colonies of northeast South Dakota, 2008 – 2009. Competitive models = (ΔAICc $\leq$ 2.0).

Model Set	**Model**	**AICc**	**ΔAICc**	**W_i**
Local & Landscape	+ HerbWet_6400 + Dev_6400 + BareGr – HVHt	1394.05	0.00	0.999
Local	+ BareGr – HVHt	1452.08	58.03	<0.001
Landscape	+ HerbWet_6400 + Dev_6400	1851.86	457.81	<0.001
Landscape	+ HerbWet_6400 + Dev_6400 + Open_400	1853.86	459.81	<0.001

CHAPTER 4

DISSCUSSION

Reproductive Success and Colony Locations

Black-crowned Night Heron

Black-crowned night heron nesting success, (52.1%) was lower in northeast South Dakota compared to other U.S. populations. Teal (1965) reported 87.5% in Georgia, Custer et al. (1983) reported nesting success for 5 colonies along the Atlantic coast ranging from 67.8% to 100%, and Hothem and Hatch (2004) reported a mean of 64% nest success at Alcatraz Island, California, from 1990 – 2002. The highest density and nesting success of BCNHs in my study occurred on island colonies with no herbaceous vegetation, which greatly reduced the potential for disturbance and predation.

Overall, BCNHs experienced lower fledging success compared to other studies. Teal (1965) found that 2.13 young were fledged per nesting attempt in a Georgia colony, Wolford and Boag (1971) reported 0.10 and 1.10 young fledged per nesting attempt in Alberta, and Price (1977) reported 0.5 – 1.4 young fledged per nest on Lake Ontario. Tremblay and Ellison (1980) reported 0.5 – 2.1 young fledged per active nest on the St. Lawrence River, Findholt (1981) reported 1.1 – 2.5 young fledged per nest in an Idaho colony, and Hoefler (1979) found a mean of 1.98 young fledged per breeding pair, and 2.42 young fledged per successful breeding pair in Wisconsin. Black-crowned night herons fledged per successful nest ranged from 2.24 in Pennsylvania (Wood and Wood 1933) to

2.43 in Georgia (Teal 1965). Hothem and Hatch (2004) reported a mean of 88% fledge success with a mean of 0.74 young fledged per nest at Alcatraz Island, California, from 1990 – 2002.

Henny (1972) found that a stable BCNH population must fledge 2.00 – 2.10 young per breeding pair. My findings suggest that the BCNH population in northeast South Dakota is declining. However, I was unable to account for possible renests. Henny (1972) reported that BCNHs readily renest and thus my estimates may have under estimated the actual number of young fledged per breeding pair. Low reproductive success in northeast South Dakota was largely a result of nest abandonment. Nest abandonment was highest on vegetated island sites, and may have been due to mammalian predators.

Colony sites of BCNHs were all on islands with 1 exception. Island colonies were surrounded by water and contained eastern redcedar trees with little herbaceous vegetation within the colony. Black-crowned night herons likely selected these sites, as they are relatively free of mammalian predators; provide a buffer against possible disturbances, as well as protection against wind. Kelly et al. (1993) reported that over 50% of BCNHs nesting in the San Francisco Bay area nested on isolated colonies presumably for protection against predators as little feeding habitat was located near the islands. Hoefler (1979) also reported BCNHs nesting on islands in association with large wetlands with equal proportions of open water and vegetated area in Wisconsin. Dead eastern redcedar trees were the most abundant trees on islands sites and provided numerous branches for supporting nests. Black-crowned night herons were observed nesting at 2 separate

vegetated colonies. However, nest success was lower at these sites, which was likely a result of predation. Black-crowned night herons also nested in inundated eastern redcedar trees at Pepper Slough in Clark County in 2009 where nest success was 0.0%. Nesting over water or on island sites with herbaceous vegetation prevented adults from moving about the colony on the ground. I observed BCNHs nesting low in trees and directly on the ground on island sites with no herbaceous vegetation. When BCNHs arrived at island sites in the spring, I observed them gathering nesting material, i.e. sticks, from the ground on island sites. Inundated colony sites provide little nesting material for BCNH nest building. Young BCNHs also moved out of the nest and were observed walking on the ground prior to fledging on islands sites. J. Kiesow (Pers. Commun.) reported that BCNHs failed to return to an island colony, characterized by bare ground, on Bitter Lake in northeast South Dakota upon becoming flooded prior to the 2010 breeding season. Flooded nesting islands limits the availability of the preferred low tree and ground nesting sites of BCNHs. Therefore, the best model for nest success included only bare ground as the most significant predictor.

Great Blue Heron

Reproductive success of GBHEs varies widely and is generally only reported as the number of young fledged per successful nest (Butler 1992). I documented significantly higher nesting success in 2009 vs. 2008 (Table 3-4), which was likely the result of 3 additional colony sites; James River near Glendale colony, James River at Brown/Spink Co. Line, and Turtle Creek at 181 St., which were dominated (> 50%) by GBHEs. In colonies where GBHEs were the most numerous nesting species, nest success averaged

78.8%. Higher nest success in these colonies was likely a result of reduced nest abandonment and takeover by DCCOs. Nest abandonment was higher in colonies were GBHEs were not the most numerous nesting species. Nest abandonment may be a result of decrease foraging availability near colony locations or increased social pressure from DCCOs. GBHE colonies located along creeks and rivers exhibited the highest nest success and were dominated by GBHEs suggesting that GBHEs are selecting more for these sites versus wetland sites. Dowd and Flake (1985) noted that GBHEs nesting along the James River in South Dakota foraged primarily in streams, rivers, and intermittent streams, which are most likely influencing colony locations.

Unsuccessful GBHE nests were largely due to nest abandonment and nest takeover. Nest abandonment was observed within mixed species colonies where partial colony abandonment occurred and with individual GBHE nests within colonies with little overall abandonment by other species. Colonies where a large amount (>50%) of total nest abandonment occurred was likely due to anthropogenic activities, i.e. boating and fishing occurring near colonies. I directly observed GBHEs and other nesting waterbirds flush from nests when boats approached colonies within 75 m. Burger (1982) found that the major causes of nest failure in colonial waterbirds were related to human activities, predation, weather, and lack of food resources.

Nest takeover was the major factor contributing to failed GBHE nesting attempts in my study. Double-crested cormorants were the only species observed to takeover GBHE nests. Thompson (1981) reported DCCOs taking over GBHE nests in Montana, but did not

witness physical takeover. The number of total nest takeovers may be a secondary result of GBHE nest abandonment or nest failure, as I did not witness actual nest takeover. Nest takeover that did occur was largely during the incubation stage. Nest takeover by DCCOs was likely due to the large DCCO population in my study area. When colonies were comprised of 50% DCCO nests, there was a 64.2% GBHE nest takeover rate. I observed GBHEs and DCCOs initiating nests at the same time; however, DCCOs continued to build nests throughout the entire breeding season. It is likely that DCCOs are attempting to renest in GBHE nests upon losing their initial nest.

Great blue heron percent fledging success and number of young fledged were lower in northeast South Dakota compared to other findings within the U.S. Pratt (1970) reported 1.5 and 1.7 young fledged per nest in a central California colony in 1967 and 1968, respectively. Henny and Bethers (1971) reported 2.04 young fledged per nest in Oregon and Pratt (1972) reported an overall mean of 70.8% fledge success and 1.9, 2.1, 2.2, and 2.3 young fledged per nest in the San Francisco Bay region from 1967 – 1970. Edford (1976) reported 2.75 and 2.90 young fledged per nest and per successful nest on Lake Erie. Warren (1979) reported 2.5 young fledged per nest in Idaho and Dowd and Flake (1984) reported 3.0 young fledged per nest on the James River near Glendale Colony in Spink County, South Dakota. I monitored the same colony in 2009 and only 1.5 young per nest were fledged. Pratt and Winkler (1985) reported a mean of 1.45 ± 0.06 young fledged per nesting attempt with a range of 0.89 to 2.38 over a 13-year period, and Butler (1992) reported the mean of means of 16 studies to be 2.3 ± 0.30 (SD) young fledged per nest. Other reported results include, means of 2.17 ± 0.37 young fledged per nest for 19 colonies

in northwest Ohio and western Pennsylvania (Carlson and McLean 1996) and 1.24 ± 0.42 young fledged per initiated nest and 2.15 ± 0.17 young fledged per successful nest in 35 colonies observed in southwest British Columbia (Vennesland and Butler 2004).

Henny (1972) defined a stable GBHE population as one which must fledge 1.91 young/breeding pair/year. My findings suggest that the GBHE population in northeast South Dakota is declining. The primary factors leading to low reproductive success in northeast South Dakota were nest abandonment and nest takeover by DCCOs. I was unable to identify direct causes of nest abandonment, but speculate that disturbance to and around colony sites is a leading factor as well as limited foraging habitat that is also void of disturbance.

Great blue herons selected colony locations that contained green ash trees, which provided suitable sites for nest placement. Dowd and Flake (1984) also found that GBHEs nesting along the James River in South Dakota selected green ash trees. Short and Cooper (1985) found that nesting locations should consist of trees with an open canopy that are > 5 m tall and cover an area of ≥ 0.4 ha over, near, or within 250 m of water. Great blue herons selected against grasslands and developed areas occurring near colonies. Developed areas are indicative of anthropogenic disturbances, which Bjorklund (1975), Werschkul et al. (1976), and Simpson et al. (1987) found to decrease reproductive success and increase colony abandonment rates in GBHE colonies. Herbaceous wetland area surrounding colonies were also positively associated with colony locations. Kelly et al. (2008) found that GBHE colonies in the northern San Francisco Bay area were selecting for colony sites

that were surrounded by estuarine emergent wetlands and open water within 1 km. Gibbs (1991) and Gibbs and Kinkel (1997) found that total wetland area, open water, and river and lake shoreline were positively correlated with GBHE colony nesting locations.

Nesting success models for GBHEs indicated that bare ground occurring on island colonies and herbaceous wetlands surrounding colonies were important habitat characteristics. Kelly et al. (2008) found that increased productivity in successful GBHE nests was positively associated with estuarine emergent wetland, open water, low intensity development and negatively associated with grasslands. Herbaceous wetland habitat surrounding colonies provides foraging habitat for adults. Close proximity of foraging habitat equals less energy spent flying to feeding areas and more food brought to nestlings. Great blue heron nest success in northeast South Dakota was negatively correlated with the percentage of DCCOs nests occurring in colonies. Social pressures in colonies dominated by DCCOs are likely leading to increased nest takeover rates of GBHEs.

Cattle Egret

Cattle egret percent nesting success was comparable to what others have reported. I recorded significantly lower nesting success in 2009 compared to 2008 (Table 3-4), which was largely due to CAEGs attempting to nest at Pepper Slough in Clark County, a colony dominated by GREGs and DCCOs. This colony consisted of inundated, dead eastern redcedar trees and CAEGs began nesting at this site late (20 July) in the breeding season. At this site, all 11 nests were abandoned prior to young hatching. These nests may have been juvenile CAEGs attempting to nest or adults re-nesting, but causes of abandonment

were unknown. Unsuccessful nests were largely attributed to nest abandonment and nest structure failure. The high rate of nest abandonment was a result of all 11 abandoned nests at Pepper Slough. Hatching success reported by others includes 30.0% in Alabama (Dusi and Dusi 1970) and 97.0% in New Jersey (Burger 1978), with most ranging from 50 to 90% (Ranglack et al. 1991). Telfair and Bister (2004) reported an overall mean of 88 and 86% hatching success at 2 colonies in northeast Texas from 1974 – 2002. Jenni (1969) reported a mean of 3.2 ± 0.09 young hatching per nest and Rodgers (1987) reported 2.50 ± 0.05 young hatching per nest, which was similar to the mean brood size of successful nests that I found in northeast South Dakota. Ranglack et al. (1991) reported 1.86 ± 0.04 young hatched per nest in an Alabama colony.

Cattle egret fledging success was 69.2%, which was higher than 14.8% and 65% reported by Dusi and Dusi (1970) and Burger (1978), respectively. Young surviving to 14 days has been reported as 2.9 ± 0.11 young per nest in Florida (Jenni 1969), 2.54 ± 0.90 (SD) on Islajo Island, New Jersey (Burger 1978), and 1.11 ± 0.03 in Alabama (Ranglack et al. 1991). Weber (1975) reported 1.8 young fledging per nest in a Florida colony, which is similar to what I found in northeast South Dakota. In Australia, the mean number of young fledged per nest over 6 years was 2.46 ± 0.81 (SD) (Maddock and Baxter 1991).

Cattle egrets selected island colony sites that were denude of herbaceous vegetation, contained dead eastern redcedar trees for nesting and were surrounded by open water. Telfair (1994) described 4 colony types in North America, (1) woodlands, (2) swamps, (3) inland wooded islands, and (4) coastal islands. Kushlan and Hancock (2005) noted that

CAEG colonies are usually located on islands surrounded by water. Cattle egrets are the most terrestrial heron (Telfair 1994), and often feed on insects in pastures (Jenni 1969, Fogarty and Hetrick 1973, McKilligan 1997) which also illustrates the importance of grasslands surrounding colonies. I observed cattle egrets foraging in both grasslands and wetlands throughout northeast South Dakota during the 2008 and 2009 breeding seasons, and Telfair (1994) described CAEGs as being highly adaptable foragers in aquatic and terrestrial habitats. Naugle et al. (1996) described that importance of temporary and seasonal wetlands within 5 km of a mixed species colony in Brown County, South Dakota. This illustrates the need for not only conserving wetlands habitat, but also surrounding grasslands.

Nest success predictive models indicated that CAEGs had the highest nest success when colonies were surrounded by wetland habitat. Within colonies, CAEGs had higher nesting success in colonies that contained a high amount of bare ground. Conversely, CAEGs had reduced nesting success when nesting in similar tree structures over water. Cattle egrets, like BCNHs were observed nesting low in trees or directly on the ground and adults were often seen walking around the colony gathering nesting material. Young CAEGs also left the nest bowl and were observed climbing in nearby branches and walking on the ground near the nest prior to fledging. Island colonies had a higher density of trees which provided more protection against weather events. J. Kiesow (Pers. Commun.) reported that CAEGs did not return to nest on a mixed species island colony on Bitter Lake in northeast South Dakota upon becoming flooded prior to the 2010 breeding season.

Great Egret

Great egret nesting success was 61.5% compared to 49% reported on Sapelo Island, Georgia (Teal 1965). Nest abandonment and nest structure were the major causes of nest failure. Nest abandonment was likely overestimated and the underlying cause was predation as most abandoned nests occurred on vegetated island colonies. I documented predation on these island colonies, but I was unable to effectively document predation rates.

Great egret fledging success (50.7%) was lower than what others have found, but the number of young fledged from nests was higher than most reported studies. Lower fledging success is attributed to sites that experienced large-scale abandonment. However, the high number of young fledged from nests is likely a result of suitable foraging habitat available near colony locations in northeast South Dakota. Pratt (1970) reported 76% and 63% fledging success in a California colony in 1967 and 1968, with 1.4 and 1.1 young fledged per nest, respectively. Pratt and Winkler (1985) reported a mean of 0.90 ± 0.04 young fledged per nest nesting attempt over a 13-year period with ranges from 0.03 to 2.04. Frederick and Collopy (1989) reported 59.7% fledge success with 1.87 ± 0.52 (SD) young fledged per successful nest. Maddock and Baxter (1991) reported a mean of 2.14 ± 0.63 (SD) young fledged per nest over 6 years in Australia. Kahl (1963) estimated that 2.92 young must be fledged per nest to maintain a stable population. However, this estimate may be too high as production rates of stable populations are less than this estimate (McCrimmon et al. 2001).

Great egrets selected colony locations that were on islands surrounded by water, and contained either bare ground or a shrub understory. Chapman and Howard (1984) found that nesting locations in the southern U.S. should consist of an island < 5 ha in size with 60% woody vegetation that is ≥ 1 m high and surrounded by water. Non-island sites should contain flooded trees with a water depth ≥ 0.6 m to deter predators. McCrimmon et al. (2001) noted that GREGs readily nest both on islands and over water. Naugle et al. (1996) noted the importance of temporary and seasonal wetlands occurring within 5 km of a colony in northeast, South Dakota, and Kelly et al. (2008) found that GREG colonies in the northern San Francisco Bay area were positively associated with estuarine emergent wetlands and open water within 1 km. Great egrets also selected for non-island sites. These sites were inundated eastern redcedar tree windbreaks. These trees are in rows and are spaced close together supporting numerous branches, which provide sturdy nest platforms. Great egrets experienced no predation at these sites, which is likely a result of the water buffer deterring mammalian predators. However, I did document predation on island colonies, specifically those that contained and understory of shrubs and herbaceous vegetation. These islands were larger, (>1.0 Ha) and capable of harboring mammalian predators.

Nest abandonment was the leading cause of GREG nesting failure documented, but is likely a secondary result of predation effects. Although, the top colony site location models indicated that GREGs were positively selecting for shrubs, the top nest success models indicated that shrubs were negatively affecting nest success. Shrubs on island colonies create an understory that is beneficial to harboring mammalian predators, which

negatively affects GREG nesting success through direct predation and may cause nest abandonment from disturbance. Kelly et al. (2008) found that increased productivity in successful GREG nests were positively associated with estuarine emergent wetland and low intensity development, and negatively associated with open water within 10 km of colony locations.

Snowy Egret

Snowy egret nesting success, (83.6%) and mean brood size was relatively high in northeast South Dakota compared to other studies within the U.S. Teal (1965) reported 37% nesting success on Sapelo Island, Georgia. Jenni (1969) reported a mean of 3.3 ± 0.10 young hatching per nest, and Maxwell and Kale (1977) reported 2.7 ± 0.08 young hatching per nest in coastal Florida. Burger (1978) reported 68% nest success when nesting in an area with cattle egrets and 88% when nesting without them with an overall average brood size of 2.2 ± 1.2 (SD) young hatching per nest. Snowy egrets nested in only two colonies of which both were monitored in 2008 and 2009. These two colonies were on islands with no herbaceous vegetation and therefore experienced little to no disturbance which could negatively influence nesting success.

Snowy egret fledging success and the number of young fledged was also higher than what most others have reported. Jenni (1969) found that 72% of nests reached an age of 14 days posthatch with a mean of 2.2 ± 0.10 young per nest in Florida, Burger (1978) reported 45% of nests reaching 4 days posthatch in New Jersey with a mean of 0.95 ± 1.3 (SD) young per nest, and St. Clair Raye and Burger (1979) reported 1.5 young per nest

surviving to 14 days in New York. Frederick and Collopy (1989) reported 2.78 ± 0.79 (SD) young fledged per successful nest in the Florida Everglades. Kelly et al. (1993) reported a mean brood size of 2.07 ± 0.73 (SD) young at 4 – 7 weeks posthatch. Findholt (1984) reported 2.0 and 2.5 young surviving per nest to 7 – 10 days posthatch in 2 colonies in Idaho, but estimated that 3.2 young fledged per nesting female are required to maintain a stable population in Idaho. This estimate may be inflated as all reported estimates of fledging rates fell below this value. Snowy egret colonies experienced little disturbance and no predation was documented which resulted in high fledge success.

Snowy egrets selected colony sites located on islands with no herbaceous vegetation and open water surrounding the island. Kelly et al. (1993) found that SNEGs nesting in the San Francisco Bay area nested on isolated colonies most likely for protection against predators as little feeding habitat was located near the islands. Parsons and Master (2000) noted increased predation at semi-isolated colonies has resulted in SNEGs nesting more exclusively on islands. Islands that are surrounded by water and contain a large percentage of bare ground provide a relatively safe location for nesting colonial waterbirds. These locations are buffered against anthropogenic activities and mammalian predators. Islands that are free of herbaceous vegetation are unable to harbor mammalian predators and enables pre-fledged young to freely move about the colony. Teal (1965), Burger (1978), and Parsons and Master (2000) found that pre-fledged SNEGs readily leave the nest bowl at 10 – 14 days and move about the colony, returning for feeding when parents arrive at nest. J. Kiesow (Pers. Commun.) reported that SNEGs did not return to nest on a mixed species island colony on Bitter Lake in northeast South Dakota upon becoming flooded

prior to the 2010 breeding season. High reproductive success of SNEGs in northeast South Dakota is likely attributed to nests being located on island colonies with bare ground which reduced predation and disturbances rates. Monitoring nests away from the islands and not physically entering colonies allowed me to obtain nest and fledge success data without entering the colonies and creating a disturbance which may also explain the higher reproductive success in my study.

Double-crested Cormorant

Double-crested cormorant nesting success, (70.4%) was higher than what most others have reported. Population dynamics of DCCOs are largely unknown compared to other widespread colonial waterbirds (Hatch and Weseloh 1999). Reported hatching success ranges from 2.4% (Weseloh et al. 1983) to 83.5% (van der Veen 1973) with a mean of 58.4 ± 7.8% for 9 studies (Hatch and Weseloh 1999). Nesting success of DCCOs was positively influenced by the amount of bare ground occurring on island nesting sites and the amount of wetland area surrounding sites. The increased amount of wetlands occurring near colonies provides additional feeding opportunities, which are positively correlated with reproductive output (Hatch and Weseloh 1999).

Nest abandonment and nest structure failure were the leading causes for nest failure. Nest abandonment occurred on individual nests within colonies, but was inflated by 4 colonies where large-scale (≥ 90%) abandonment occurred. Colonies with high abandonment rates were likely due to repeated anthropogenic disturbances that I witnessed near (< 100 m) colonies, i.e. boating and fishing which resulted in large numbers of

DCCOs repeatedly flushing from nests. Burger (1982) and Hatch and Weseloh (1999) noted that if a disturbance is repeated colonial waterbirds will completely abandon the colony. Double-crested cormorants are widespread nesters in northeast, South Dakota (Drilling 2007) which greatly increases the likelihood of a portion of colonies to experience disturbance. Nest structure failure was observed in all colonies except 1 and was largely a result of high winds as nearly all DCCO colonies were located in wetlands, and nested in tall, dead inundated trees with little protection from high winds.

Double-crested cormorant fledging success, (54.2%) and number of young fledged where comparable to what others have reported. Reinhold et al. (1998) reported 41.9% of nests fledging young in a Mississippi colony. Authors reporting the number of young fledged per nest include 0.98 in Quebec (Ellison and Cleary 1978), 2.3 ± 1.2 in South Carolina (Pilon et al. 1983), and 1.27 in California (Stenzel et al. 1995). Fledge success may be underestimated in my study as I was unable to account for possible renests. Colonies that experienced high abandonment rates may have renested in nearby colonies.

Double-crested cormorants nested in nearly all the colonies I monitored, and selected for both island and inundated colony sites. Island colonies were denude of herbaceous vegetation and were surrounded by open water. Lack of herbaceous vegetation on island colonies and a water buffer protects nesting DCCOs as well as other colonial waterbirds from mammalian predators. Thompson (1981) hypothesized that DCCOs selected arboreal nesting colony sites near large bodies of water for feeding and with water surrounding the colony for protection from ground predators. I also observed DCCOs

nesting directly on the ground as reported by Hatch and Weseloh (1999). Double-crested cormorants also nested in dead inundated trees on the periphery of mixed species, island colonies. The totipalmate webbed foot style of DCCOs is likely a disadvantage to nesting within live trees with numerous branches, which is characteristic of some island sites.

Colony Nesting and Fledging Success

Colony nesting and fledging success was highly variable among colonies, while individual species success was relatively reflective of each other. Colonies that experienced the lowest nesting and fledging success rates were sites with high nest abandonment. Colonies with low reproductive success indicated high amounts of anthropogenic disturbance and or predation rates leading to nest abandonment and direct nest failure. Nest abandonment is likely not related to forage availability due to the high density of wetlands in northeast South Dakota. Colony nesting and fledging success was reflective of overall species success. However, colony nesting and fledging success could be used as an index of overall reproductive success among colonies in northeast South Dakota.

Nest Monitoring Methodology

I observed nests from a distance in this study to mitigate observer disturbances, which have been shown to lower reproductive success of colonial nesting waterbirds. When comparing reproductive success in northeast South Dakota to other research studies, my findings were variable among species. Black-crowned night herons and GBHEs exhibited lower nesting success than what has been reported elsewhere. However, CAEGs, GREGs, SNEGs, and DCCOs had relatively high reproductive success when compared to other areas. While most reproductive studies on these species have been conducted in coastal

U.S. populations, it is difficult to make direct comparisons of how nest observation methodology affects reproductive success. In addition, nest success for colonial nesting waterbirds can be highly variable among regions and years (McCrimmon et al. 2001).

Monitoring nests from a distance allowed me to increase the number and diversity of colonies monitored. Also, by not entering colonies I was able to view nests on a weekly basis from nest initiation until nest failure or fledging was documented. When researchers enter colonies they often do not monitor nests throughout the entire breeding season and do not account for unmarked nests that were abandoned or failed due to researcher related disturbances. Studies of reproductive success involving researchers entering colonies have generally been on a relatively small scale and have been focused on larger colonies. Birds in large colonies may become habituated to a researcher entering the colony and the disturbance may not be great enough to cause the entire colony to flush from nests. The nest observation methodology I used in this study allowed me to focus on a larger geographic area with increased nests monitored, which allows for more sound conclusions to be drawn on larger populations.

Conclusions

My findings indicate that colonial tree-nesting waterbird reproductive success in northeast South Dakota is variable among species. Great blue herons are extremely widespread nesters, but exhibited relatively low nest and fledge success. Black-crowned night herons nested in low densities and experienced low nest success compared to other areas, which was mostly due to nest abandonment that occurred on vegetated island colonies. Cattle egret, GREG, and SNEG nesting and fledging success rates were

comparable to other findings across their range, but nested in low densities, and only in a few colonies. Double-crested Cormorants were the most numerous colonial tree-nesting waterbird, and nesting and fledging success was relatively high.

The most important aspect of managing for colonial tree-nesting waterbirds in northeast South Dakota is protecting colony sites from disturbances. Disturbances, whether anthropogenic or mammalian, lead to nest and colony abandonment as well as direct nest loss. In addition to colony site protection, wetland and grassland habitat must remain on the landscape to provide foraging areas and opportunities for new colony site locations.

CHAPTER 5

MANAGEMENT IMPLICATIONS

Reproductive success of colonial tree-nesting waterbirds is extremely valuable information for wildlife and land managers. Waterbirds are sensitive to environmental change (Temple and Wiens 1989), and from a management standpoint, they are useful bioindicators of wetland productivity, trophic structure, human disturbances, and contaminations in wetlands (Custer and Osborn 1977). My results indicate that management of colonial tree-nesting waterbirds should be conducted at both the local and landscape levels, as nesting and fledging success is largely influenced by colony site and landscape characteristics.

Colony Preservation

Island colonies contained the most diverse and numerous nesting activities and exhibited the highest reproductive success. Established larger colonies such as island sites are more productive compared to smaller, pioneering colonies, and should therefore be preserved (Butler et al. 1995). Black-crowned night herons, CAEGs, and SNEGs nested almost exclusively on islands, and GREGs also showed a high affinity for island sites, but also nested over water. The best predictive colony site models developed for these 4 species all included bare ground and open water surrounding the colony, which is indicative of island colonies. In particular, BCNH, CAEG, GREG, and SNEG colonies need to be conserved as they nested in only a few sites and at low densities. Great blue herons are the most widespread nesting colonial waterbird in South Dakota (Drilling 2007),

but also had the lowest reproductive success. It is important to preserve sites containing large numbers of GBHEs, especially riverine colonies. When GBHEs nested in larger concentrations their reproductive success increased. When GBHEs nested in smaller concentrations in association with DCCOs, their reproductive success was considerably lower. Although DCCOs may have a negative impact on nesting GBHEs, the most critical issue for GBHE conservation across their range is colony site protection (Kushlan and Hancock 2005). Double-crested cormorants are the most numerous colonial tree-nesting waterbird in South Dakota (Drilling 2007) and exhibited relatively high reproductive success compared to other colonial tree-nesting waterbirds.

Preservation of existing colony sites is a high priority for the continued well-being of colonial tree-nesting waterbirds in northeast South Dakota. Existing large mixed species colonies containing BCNHs and GBHEs should be of greatest importance, as well as colonies dominated by GBHEs. Drilling (2007) identified important colonies in South Dakota as those that contained ≥ 200 breeding pairs or > 5 nesting species. Although it is crucial to conserve large colonies, Hafner (2000) noted that very large colonies are more vulnerable than numerous smaller colonies. Therefore, it is extremely important to protect the larger colonies occurring in northeast South Dakota. Hafner (2000) also suggested that when there are fewer, larger colonies in an area it is indicative of a lack of suitable colony nesting sites, not the availability of feeding areas. Drilling (2007) found that all species except DCCO and GBHE nested in at least 1 colony that contained >25% of their known breeding population in South Dakota.

Colony site protection is critical for all colonial waterbirds. The PPR, northeast South Dakota in particular, has been transformed into a highly fragmented agricultural landscape (Naugle et al. 2000). A fragmented landscape drastically alters the juxtaposition of resources, reducing the proximity of foraging sites and increasing colony and foraging disturbance rates. Successful colonies, therefore must be positioned where they are safe from predators and within commuting distance of food resources (Fasola and Alieri 1992). The availability of foraging habitat directly reflects population numbers of wading birds (Kushlan 1978), and colony site locations are greatly explained by the location of foraging habitats (Butler 1991, Gibbs 1991).

Wetland Conservation

In addition to preserving existing colony sites, it is essential that managers work to conserve wetland habitats and islands existing in northeast South Dakota. Existing colony sites slowly deteriorate over time (Anderson and Hamerstrom 1967, Mitchell 1975, Findholt 1988), and shift across the landscape in response to natural hydrologic cycles (Naugle et al. 1996, Murkin et al. 1997). Therefore, it is important that suitable nesting habitat is available on the landscape. Drilling (2007) found that several large historic colonies in South Dakota moved as a result of flooding or persistent drought. With deteriorating island nesting sites in northeast South Dakota, it may be necessary to enhance or create islands to provide ample waterbird nesting opportunity.

It is necessary to provide wetland habitat for both nesting and foraging across the landscape. Currently, potential colony site locations and foraging habitat are continually

being lost not only in South Dakota, but also across the entire range of many waterbird species (Kushlan and Hancock 2005). Within the PPR, over 50% of the historic wetlands have been drained for agricultural development (Euliss et al. 2006). A substantial amount of wetland habitat exists in northeast South Dakota (Johnson et al. 1997), as well as a large quantity of inundated trees for nesting sites (Naugle et al. 1996). My results indicate the importance of protecting wetlands in the surrounding landscape.

Increased amount of wetland and grassland conversion, largely fueled by the corn ethanol industry, is greatly threatening the quality and quantity of these habitats (Brooke et al. 2009). The best predictive models created for colony site locations for all 6 colonial tree-nesting waterbird study species included both local and landscape variables. A major landscape variable occurring in models was the need for wetland area surrounding colonies. I concur with Naugle et al. (2001) and Kushlan and Hancock (2005) who stressed the importance of wetland conservation and landscape level management to preserve potential waterbird nesting and foraging sites.

Colonial tree-nesting waterbirds, as well as other waterbird species, can be greatly impacted by catastrophic events, such as the ecological trap of the Salton Sea, USA (Kushlan and Hancock 2005) and the 2010 oil spill in the Gulf of Mexico. The Deepwater Horizon oil spill has the potential to be extremely detrimental to the large concentrations of breeding and wintering waterbirds along the Gulf coast. Butler et al. (2000) and Kushlan and Hancock (2005) classified the Louisiana coastal swamps as important areas for herons in North America. Parsons (1994) documented a drastic decline in SNEG nestlings in New

York Harbor following an oil spill that degraded wetland foraging habitat. As wetlands continue to be degraded and lost throughout the U.S. it is more critical now than ever before to conserve the wetland resources in northeast South Dakota for nesting and foraging waterbirds.

Recommendations for Future Research

Future research should focus on identifying foraging locations and distance of foraging flights from colonies for all species of colonial tree-nesting waterbirds nesting in South Dakota as Dowd and Flake (1985) conducted for GBHEs nesting on the James River. Identification of primary foraging habitats located in close proximity to major wetland complexes should be identified and preserved, as well as potential colony site nesting locations within these areas.

Reproductive success of GBHEs was relatively low in northeast South Dakota, however, Drilling (2007) noted that they are the most widespread colonial nesting waterbird in South Dakota. Great blue herons nested in the largest densities and exhibited the highest success when nesting in riverine environments. Therefore, reproductive success of GBHEs should be evaluated throughout South Dakota, focusing on these riverine colony sites.

The double-crested cormorant population should be continually monitored with emphasis on the interaction between DCCOs and GBHEs. Great blue heron nesting pairs and success should be continually monitored at sites that are largely (>50%) comprised of GBHEs as DCCOs could possibly exclude GBHEs, ultimately lowering their reproductive

success. Great blue heron nesting success is low in northeast South Dakota, which suggests that the population is declining. It is essential to determine the exact causes of GBHE nest abandonment. Renesting of DCCOs as well GBHEs should be evaluated. Double-crested cormorant colonies that experienced high rates of abandonment early in the breeding season are likely redistributing to nearby colonies and renesting. As I was unable to document renesting events, the reproductive success of DCCOs is likely greater than reported.

Black-crowned night herons, CAEGs, GREGs, and SNEGs nested almost exclusively on island sites. The leading causes of nest failure for these species were nest abandonment and predation, which occurred on vegetated islands where mammalian predators were present. In order to alleviate the predation effects, which are likely leading to large-scale colony abandonment, predator control prior to the nesting season could be an option.

Continued censusing of colonial tree-nesting waterbird numbers and colonies is critical. Wetlands are being drained at an unprecedented rate in eastern South Dakota and it is vital to continue to monitor waterbird colonies, as they are highly dependent upon these wetlands for foraging and nesting. Colonies of high importance should be the primary sites for continued monitoring. Reproductive success should also be evaluated on larger, important colonial tree-nesting waterbird colonies as identified by Drilling (2007) that occur outside of my study area. Land use characteristics surrounding these colonies should also be evaluated, and the colony sites must be protected from disturbances. Censusing and

continued monitoring of active colonies and species numbers are essential, especially within the interior U.S. (Kushlan and Hancock 2005). Reproductive success, and nesting and fledging rates should also continue to be evaluated on high importance colonies, as these parameters are a reflection of habitat quality and quantity.

LITERATURE CITED

Akaike, H. 1969. Fitting autoregressive models for prediction. Annals Institute Statistics. Mathematics 21:243-247.

Anderson, D. W. and F. Hamerstrom. 1967. The recent status of Wisconsin Cormorants. Passenger Pigeon 29:3-15.

Anderson, D. W. and J. O. Keith. 1980. The human influence on seabird nesting success: conservation implications. Biological Conservation 18:65-80.

Bailey, A. W. and C. E. Poulton. 1968. Plant communities and environmental relationships in a portion of the Tillamook burn, Northwestern Oregon. Ecology 49:1-13.

Bakker, K. K. 2005. South Dakota all bird conservation plan. South Dakota Department of Game, Fish, and Parks, Pierre, SD.

Baxter, G. S. 1994. The influence of synchronous breeding, natal tree position and rainfall on egret nesting success. Colonial Waterbirds 17:120-129.

Beyersbergen, G. W., N. D. Niemuth, and M. R. Norton, (coordinators). 2004. Northern Prairie and Parkland Waterbird Conservation Plan. A plan associated with the Waterbird Conservation for the Americas Initiative. Published by the Prairie Pothole Joint Venture, Denver, CO. 183 pp.

Bjorklund, R. G. 1975. On the death of a midwestern heronry. Wilson Bulletin 87:284-287.

Brooke, R., G. Fogel, A. Glaser, E. Griffin, K. Johnson. 2009. Corn ethanol and wildlife. How increases in corn plantings are affecting habitat and wildlife in the Prairie Pothole Region. National Wildlife Federation 27 pp.

Bryce, S., J. M. Omernik, D. E. Pater, M. Ulmer, J. Scharr, J. Freeouf, R. Johnson, P. Kuck, and S. H. Azevedo. 1998. Ecoregions of North Dakota and South Dakota. Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/habitat/ndsdeco/index.htm (Version 30NOV98).

Burger, J. 1978. Competition between cattle egrets and native North American herons, egrets, and ibises. Condor 80:15-23.

Burger, J. 1981. Effects of human disturbance on colonial species, particularly gulls. Colonial Waterbirds 4:28-36.

Burger, J. 1982. An overview of proximate factors affecting reproductive success in colonial birds: concluding remarks and summary of panel discussion. Colonial Waterbirds 5:58-65.

Burger, J. and M. Gochfeld. 1983. Behavioural responses to human intruders of Herring Gulls (*Larus argentatus*) and Great Black-backed Gulls (*L. marinus*) with varying exposure to human disturbance. Behavioural Processes 8:326-344.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach. Springer-Verlag, New York, NY, USA.

Butler, R. W. 1991. Habitat selection and time of breeding in the Great Blue Heron (*Ardea herodias*). PhD. Dissertation, University of British Columbia, Canada.

Butler, R. W. 1992. Great Blue Heron (*Ardea herodias*). *In* The Birds of North America, No. 25 (A. Poole, P. Stet10heim, and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, DC: The American Ornithologists' Union.

Butler, R. W., J. A. Kushlan, and I. J. Davidson. 2000. Pp.151-175 *in* Heron Conservation (J. Kushlan and H. Hafner eds.) Academic Press, San Diego, CA. 480 pp.

Butler, R. W., P. E. Whitehead, A. M. Breault, and I. E. Moul. 1995. Colony effects on fledging success of Great Blue Herons (*Ardea herodias*) in British Columbia. Colonial Waterbirds 18:159-165.

Carlson, B. A. and E. B. McLean. 1996. Buffer z1s and disturbance types as predictors of fledging success in great blue herons. Colonial Waterbirds 19:124-127.

Carney, K. M. and W. J. Sydeman. 1999. A review of human disturbance effects on nesting colonial waterbirds. Waterbirds 22:68-79.

Chapdelaine, G. and J. Bédard. 1995. Recent changes in the abundance and distribution of the Double-crested Cormorant (*Phalacrocorax auritus*) in the St. Lawrence River, Estuary and Gulf, Quebec, 1978-1990. In The Double-crested Cormorant: biology, conservation and management (D.N. Nettleship and D.C. Duffy, Eds.). Colonial Waterbirds 18 (Special Publication 1). 18:70-77.

Chapman, B. R. and R. J. Howard. 1984. Habitat suitability index models: great egret. U.S. Fish Wildl. Serv. FWS/OBS-82/10.78 23 pp.

Conover, M. R. and D. E. Miller. 1978. Reaction of ring-billed gulls to predators and human disturbances at their breeding site. Proceedings of the Colonial Waterbird Group 2:41-47.

Cottam. G. and J. T. Curtis. 1956. The use of distance measures in phytosociolgical sampling. Ecology 37:451-460.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. USFWS FWS/OBS-79/31. Washington, DC: GPO.

Craven, S. R. and E. Lev. 1987. Double-crested Cormorants in the Apostle Islands, Wisconsin, USA: population trends, food habits and fishery depredations. Colonial Waterbirds 10:64-71.

Custer, T. W. and R. G. Osborn. 1977. Wading birds as biological indicators: 1975 Colony survey. U.S. Fish Wildl. Serv. Spec. Sci. Rep. No. 206. Washington, D.C.

Custer, T. W., G. L. Hensler, and T. E. Kaiser. 1983. Clutch size, reproductive success, and organochlorine contaminants in Atlantic coast Black-crowned Night-Herons. Auk 100:699-710.

Daubenmire, R. 1959. A canopy-coverage method of vegetation analysis. Northwest Scientist 33:43-64.

Davis, W. E., Jr. 1993. Black-crowned Night-Heron (Nycticorax nycticorax). *In* The Birds of North America, No. 74 (A. Poole and F. Gill, eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Dieter, C. D. 1991. Water turbidity in tilled and untilled prairie wetlands. Journal of Freshwater Ecology 6:185-189.

Dowd, E. M. and L. D. Flake. 1984. Great Blue Heron nesting biology on the James River in South Dakota. Prairie Naturalist 16:159-166.

Dowd, E. M. and L. D. Flake. 1985. Foraging habitats and movements of nesting Great Blue Herons in a prairie river ecosystem, South Dakota. Journal of Field Ornithology 56 379-387.

Drilling, N. E. 2007. South Dakota Statewide Colonial and Semi-colonial Waterbird Inventory with a Plan for Long-term Monitoring: Final Report. SDGFP Wildlife Division Report 2008-01A. RMBO Tech. Rep. M-ColonySD-04. Rocky Mountain Bird Observatory, Brighton, CO. 80 pp.

Dusi, J. L. and R. T. Dusi. 1970. Nesting success and mortality of nestlings in a cattle egret colony. Wilson Bulletin 82:458-460.

Edford, L. H. 1976. Breeding biology of the great blue heron in southwestern Lake Erie. M.S. Thesis. Ohio State Univ., Columbus. 152 pp.

Ellison, L. M. and L. Cleary. 1978. Effects of human disturbance on breeding Double-crested Cormorants. Auk 95:510-517.

Erwin, L. M. 1989. Responses to intruders by birds nesting in colonies: Experimental results and management guidelines. Colonial Waterbirds 12:104-108.

Erwin, R. M. and T. W. Custer. 1982. Estimating reproductive success in colonial waterbirds: an evaluation. Colonial Waterbirds 5:49-56.

Euliss, N. H., Jr., D. M. Mushet, and D. A. Wrubleski. 1999. Wetlands of the Prairie Pothole Region: Invertebrate Species Composition, Ecology, and Management. Pp. 471-514 in D. P. Batzer, R. B. Rader and S. A. Wissinger, eds. *Invertebrates in Freshwater Wetlands of North America: Ecology and Management*, Chapter 21. John Wiley and Sons, New York. Jamestown, ND: Northern Prairie Wildlife Research Center Home Page. http://www.npwrc.usgs.gov/resource/1999/pothole/pothole.htm (Version02SEP99).

Euliss, N. H., R. A. Gleason, A. Olness, R. L. McDougal, H. R. Murkin, R. D. Robarts, R. A. Bourbonniere, and B. G. Warner. 2006. North American prairie wetlands are important nonforested land-based carbon storages sites. Science of the Total Environment 361:179-188.

Fasola, M. and R. Alieri. 1992. Conservation of heronry Ardeidae sites in North Italian agricultural landscapes. Biological Conservation 62:219-228.

Fetterolf, P. M. 1983. Effects of investigator activity on Ring-billed Gull behavior and reproductive performance. Wilson Bulletin 95:23-41.

Findholt, S. L. 1981. Organochlorine pollutants, eggshell quality and reproductive success in Black-crowned Night Herons. Unpublished M.S. Thesis, Pocatello, Idaho, Idaho State Univ.

Findholt, S. L. 1984. Organochlorine residues, egg shell thickness and reproductive success of snowy egrets *Egretta thula* nesting in Idaho, USA. Condor 86:163-169.

Findholt, S. L. 1988. Status, distribution and habitat affinities of Double-crested Cormorant nesting colonies in Wyoming. Colonial Waterbirds 11:245-251.

Fogarty, M. J. and W. M. Hetrick. 1973. Summer foods of Cattle Egrets in north central Florida. The Auk 90:268-280.

Frederick, P. C. and M. W. Collopy. 1989. Nesting success of 5 ciconiiform species in relation to water conditions in the Florida everglades. The Auk 106:625-634

Gibbs, J. P. 1991. Spatial realtionships between nesting colonies and foraging areas of Great Blue Herons. The Auk 108:764-770.

Gibbs, J. P. and L. K. Kinkel. 1997. Determinants of the size and location of Great Blue Heron colonies. Colonial Waterbirds 20:1-7.

Gillet, W. H., J. L. Hayward, and J. F. Stout. 1975. Effects on human activities on egg and chick mortality in a Glaucous-winged Gull colony. Condor 77:492-495.

Gochfeld, M. 1981. Differences in behavioral responses of young Common Terns and Black Skimmers to intrusion and handling. Colonial Waterbirds 4:47-53.

Graham, M. H. 2003. Confronting multicollinearity in ecological multiple regression. Ecology 84:2809-15.

Hafner, H. 2000. Heron nest site conservation. Pp. 201-217 *in* Heron Conservation (J. Kushlan and H. Hafner eds.) Academic Press, San Diego, CA. 480 pp.

Hansen, A. J., S. L. Garman, and B. Marks. 1993. An approach for managing vertebrate diversity across multiple-use landscapes. Ecological Applications 3:481-496.

Hatch, J. J. 1984. Rapid increase of Double-crested Cormorants nesting in southern New England. American Birds 38:984-988.

Hatch, J. J. and D. V. Weseloh. 1999. Double-crested Cormorant (*Phalacrocorax auritus*). *In* The Birds of North America, No. 441 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia. PA.

Henny, C. J. 1972. An analysis of the population dynamics of selected avian species, with special reference to changes during the modern pesticide era. U.S. Fish Wildl. Serv. Wildl. Res. Rept. 1.

Henny, C. J. and M. R. Bethers. 1971. Population ecology of the great blue heron with special reference to western Oregon. Can. Field-Nat. 85:205-209.

Hoefler, J. E. 1979. Status and distribution of Black-crowned Night Herons in Wisconsin. Proc. Colonial Waterbird Group 3:75-84.

Homer, C., C. Huang, L. Yang, B. Wylie, and M. Coan. 2004. Development of a 2001 National Landcover Database for the United States. Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 7, July 2004, pp. 829-840.

Hosmer, D. W. and S. Lemeshow. 1989. Applied logistic regression. John Wiley and Sons, New York.

Hothem, R. L. and D. Hatch. 2004. Reproductive success of the Black-crowned Night Heron at Alcatraz Island, San Francisco Bay, California, 1990 – 2002. Waterbirds 27:112-125.

Jenni, D. A. 1969. A study of the ecology of 4 species of herons during the breeding season at Lake Alice, Alachua County. Florida. Ecological Monographs 39:245-270.

Johnson, R. R., K. F. Higgins, M. L. Kjellsen, and C. R. Elliott. 1997. Eastern South Dakota wetlands. Brookings: South Dakota State University. 28 pp.

Kahl, P. M. 1963. Mortality of common egrets and other herons. The Auk 80:295-300.

Kantrud, H. A. and R. E. Stewart. 1984. Ecological distribution and crude density of breeding birds on prairie wetlands. Journal of Wildlife Management 48:426-437.

Kelly, J. P., H. M. Pratt, and P. L. Greene. 1993. The distribution, reproductive success, and habitat characteristics of heron and egret breeding colonies in the San Francisco Bay area. Colonial Waterbirds 16:18-27.

Kelly, J. P., D. Stralberg, K. Etienne, and M. McCaustland. 2008. Landscape influence on the quality of heron and egret colony sites. Wetlands 28:257-275.

Klein, M. L. 1993. Waterbird behavioral responses to human disturbances. Wilson Bulletin 21:31-39.

Kury, C. R. and M. Gochfield. 1975. Human interference and gull predation in cormorant colonies. Biological Conservation 8:23-34.

Kushlan, J. A. 1978. Feeding ecology of wading birds. Pp. 249-297 *in* Wading birds (Sprunt et al., Eds.). National Audubon Society. Rep. No. 7, New York.

Kushlan, J. A. 1992. Population biology and conservation of colonial wading birds. Colonial Waterbirds 15:1-7.

Kushlan, J. A. and H. Hafner. 2000. Heron Conservation. Academic Press, San Diego, CA. 480 pp.

Kushlan, J. A. and J. A. Hancock. 2005. The Herons. Oxford University Press Inc., Oxford, NY. 433 pp.

Kushlan, J. A., M. J. Steinkamp, K. C. Parsons, J. Capp, M. A. Cruz, M. Coulter, I. Davidson, L. Dickson, N. Edelson, R. Elliot, R. M. Erwin, S. Hatch, S. Kress, R. Milko, S. Miller, K. Mills, R. Paul, R. Phillips, J. E. Saliva, B. Sydeman, J. Trapp, J. Wheeler, and K. Wohl. 2002. Waterird Conservation for the Americas: The North

American Waterbird Conservation Plan, Version 1. Waterbird Conservation for the Americas, Washington, D.C., USA, 78 pp.

Ludwig, J. P. 1984. Decline, resurgence and population dynamics of Michigan and Great Lakes Double-crested Cormorants. Jack-Pine Warbler 62:90-102.

Maddock, M. and G.S. Baxter. 1991. Breeding success of egrets related to rainfall: a 6-year Australian study. Colonial Waterbirds 14:133-139.

Maxwell, G. R. and H. W. Kale. 1977. Breeding biology of 5 species of herons in coastal Florida. The Auk 94:689-700.

McCrimmon, D. A., Jr., J. C. Ogden, and G. T. Bancroft. 2001. Great Egret (*Ardea alba*). *In* The Birds of North America, No. 570 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

McKilligan, N. G. 1997. A long term study of factors influencing the breeding success of the Cattle Egret in Australia. Colonial Waterbirds 20:419-428.

McVaugh, W., Jr. 1972. The development of 4 North American herons. Living Bird 11:155-173.

Milton, G. R. and P. J. Austin-Smith. 1983. Changes in the abundance and distribution of Double-crested (*Phalacrocorax auritus*) and Great Cormorants (*P. carbo*) in Nova Scotia. Colonial Waterbirds 6:130-138.

Mitchell, R. M. 1975. Current status of the Double-crested Cormorant in Utah: a plea for protection. American Birds 29:927-930.

Murkin, H. R., E. J. Murkin, and J. P. Ball. 1997. Avian habitat selection and prairie wetland dynamics: a 10-year experiment. Ecological Applications 7:1144-1159

Naugle, D. E. 1997. Habitat requirements of prairie wetland birds in eastern South Dakota. Ph.D. Dissertation, South Dakota State University, Brookings.

Naugle, D. E., K. F. Higgins, M. E. Estey, R. R. Johnson, and S. M. Nusser. 2000. Local and landscape-level factors influencing black tern habitat suitability. Journal of Wildlife Management 64:253-260.

Naugle, D. E., R. R. Johnson, W. A. Meeks, and K. F. Higgins. 1996. Colonization and growth of a mixed-species heronry in South Dakota. Colonial Waterbirds 19:199-206.

Naugle, D. E., R. R. Johnson, M. E. Estey, and K. F. Higgins. 2001. A landscape approach to conserving wetland bird habitat in the prairie pothole region of eastern South Dakota. Wetlands 21:1-17.

Niemuth, N. D. and J. W. Solberg. 2003. Response of waterbirds to number of wetlands in the prairie pothole region of North Dakota, U.S.A. Waterbirds 26:233-238.

Nisbet, I. C. T. 2000. Disturbance, habituation, and management of waterbird colonies. Waterbirds 23:321-332.

Parnell, J. F., D. G. Ainley, H. Blokpoel, B. Cain, T. W. Custer, J. L. Dusi, S. Kress, J. A. Kushlan, W. E. Southern, L. E. Stenzel, and B. C. Thompson. 1988. Colonial waterbird management in North America. Colonial Waterbirds 2:129-345.

Parsons, K. C. 1994. The Arthur Kill oil spills: biological effects in birds. Pp. 215-237 *in* Before and after an oil spill (J.Burger, ed.). Rutgers Univ. Press, New Brunswick, NJ.

Parsons, K. C. and J. Burger. 1982. Human disturbance and nestling behavior in Black-crowned Night Herons. Condor 84:184-187.

Parsons, K. C. and T. L. Master. 2000. Snowy Egret (*Egretta thula*). *In* The Birds of North America, No. 489 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Pilon, C., J. B. Burton, and R. McNeil. 1983. Reproduction du Grand Cormoran (*Phalacrocorax carbo*) et du Cormoran à aigrettes (*P. auritus*) aux îles de la Madeleine, Québec. Canadian Journal of Zoology 61:524-536.

Pratt, H. M. 1970. Breeding biology of great blue herons and common erets in central California. Condor 72:407-416.

Pratt, H. M. 1972. Nesting success of common egrets and great blue herons in the San Francisco Bay region. Condor 74:447-453

Pratt, H. M. and D. W. Winkler. 1985. Clutch size, timing of laying, and reproductive success in a colony of great blue herons and great egrets. The Auk 102:49-63.

Price, I. M. 1977. Environmental contaminants in relation to Canadian wildlife. Trans. North Amer. Wildl. Nat. Resources Conf. 42: 382-396.

Ranglack, G. S., R. A. Argus, and K. R. Marion. 1991. Physical and temporal factors influencing breeding success of cattle egrets (*Bubulcus ibis*) in a west Alabama colony. Colonial Waterbirds 14:140-149.

Reinhold, D. S., A. J. Mueller, and G. Ellis. 1998. Observations of nesting double-crested cormorants in the delta region of Mississippi. Colonial Waterbirds 21:450-451.

Robert, H. C. and C. J. Ralph. 1975. Effects of human disturbance on the breeding success of gulls. Condor 77:495-499.

Rodgers, J. A. 1987. Breeding chronology and reproductive success of Cattle Egrets and Little Blue Herons on the west coast of Florida, USA. Colonial Waterbirds 10:38-44.

Rodgers, J. A. and H. T. Smith. 1995. Set-back distances to protect nesting bird colonies from human disturbances in Florida. Conservation Biology 9:89-99.

St. Clair Raye, S. and J. Burger. 1979. Behavioral determinants of nestling success of snowy egrets *Leucophoyx thula*. American Midland Naturalist 102:76-85.

Scharf, W. C. and G. W. Shugart. 1981. Recent increases in Double-crested Cormorants in the United States Great Lakes. American Birds 35:910-911.

Short, H. L. and R. J. Cooper. 1985. Habitat suitability index models: Great blue heron. U.S. Fish Wildl. Serv. Biol. Rep. 82(10.99). 23 pp.

Siegel-Causey, D. and G. L. Hunt. 1981. Colonial defense behavior in Double-crested and Pelagic cormorants. The Auk 98:522-531.

Simpson, K., J. N. M. Smith, and J. P. Kelsall. 1987. Correlates and consequences of coloniality in Great Blue Herons. Canadian Journal of Zoology 65:572-577.

Skagen, S. K., C. P. Melcher, and E. Muths. 2001. The interplay of habitat change, human disturbance and species interactions in a waterbird colony. American Midland Naturalist 145:18-28.

South Dakota Department of Game, Fish and Parks. 2006. South Dakota comprehensive wildlife conservation plan. South Dakota Dept. of Game, Fish, and Parks, Pierre, Wildlife Division Report 2006-08.

Statistix. 2003. Statistix 8.0 analytical software.

Stenzel, L. E., H. R. Carter, R. D. Henderson, S. D. Emslie, J. D. Rauzon, G. W. Page, and P. Y. O'Brien. 1995. Breeding success of Double-crested Cormorants in the San Francisco Bay area, California. Colonial Waterbirds 18 (Special Publication 1):216-224.

Systat. 2007. Systat 12 software for Windows user guide. Systat Software, Inc., San Jose, CA.

Tallman, D. A., D. L. Swanson, and J. S. Palmer. 2002. Birds of South Dakota. 3rd ed. Midstates/Quality Quick Print, Aberdeen, SD. 441 pp.

Teal, J. M. 1965. Nesting success of egrets and herons in Georgia. Wilson Bulletin 77:257-263.

Telfair, R. C. II. 1994. Cattle Egret (*Bubulcus ibis*). *In* The Birds of North America, No. 113 (A. Poole and F. Gill, Eds.). Philadelphia: The Academy of Natural Sciences; Washington, D.C.: The American Ornithologists' Union.

Telfair, R. C. II. and T. J. Bister. 2004. Long-term breeding success of the cattle egret in Texas. Waterbirds 27:69-78.

Temple, S. A. and J. A. Wiens. 1989. Bird populations and environmental changes: Can birds be bio-indicators? American Birds Summer: 260-270.

Thompson, L. S., 1981. Nest-tree sharing by herons and coromorants in Montana. Canadian Field-Naturalist 95:257-260.

Tremblay, J. and C. Ellison. 1979. Effects of human disturbance on breeding of Black-crowned Night Herons. Auk 96:364-369.

Tremblay, J., & L. N. Ellison. 1980. Breeding success of the Black-crowned Night Heron in the St. Lawrence Estuary. Canadian Journal of Zoology 58: 1259-1263.

USFWS, 2003. Final Environmental Impact Statement. Double-crested Cormorant Management in the United States. U.S. Department of the Interior Fish and Wildlife Service in cooperation with U.S. Department of Agriculture APHIS Wildlife Services Steve Williams 208 pp.

van der Veen, H. E. 1973. Some aspects of the breeding biology and demography of the Double-crested Cormorants (*Phalacrocorax auritus*) of Mandarte Island. Ph.D. thesis, Zoologisch Laboratorium der Rijksuniversiteit te Groningen, Groningen.

Vennesland, R. G. and R. W. Butler. 2004. Factors influencing Great Blue Heron nesting productivity on the Pacific Coast of Canada from 1998-1999. Waterbirds 27:289-296.

Vermeer, K. and L. Rankin. 1984. Population trends in nesting Double-crested and Pelagic Cormorants in Canada. Murrelet 65:1-9.

Warren, N. M. 1979. Ecology of great blue herons on Silver Creek, Idaho. M.S. Thesis. Univ. of Idaho, Moscow. 63 pp.

Weber, W. J. 1975. Notes on Cattle Egret breeding. Auk 92:111-117.

Weber, M. J., P. A. Vohs, Jr. and L. D. Flake. 1982. Use of prairie wetlands by selected bird species in South Dakota. Wilson Bulletin 94:550-554.

Weins, J. A., J. T. Rotenberry, and B. Van Horne. 1986. A lesson in the limitations of field experiments: shrub steppe birds and habitat alteration. Ecology 67:365-376.

Werschkul, D. F., E. MacMahan, and M. Leitschut. 1976. Some effects on human activities on the Great Blue Heron in Oregon. Wilson Bulletin 88:660-662.

Weseloh, D. V., S. Brechtel, and R. D. Burns. 1977. Recent population changes in Double-crested Cormorant and California and Ring-billed Gulls in Alberta, Canada, with a note on White Pelicans. Proceedings of the Colonial Waterbird Group Conference 1:10-18.

Weseloh, D. V., S. M. Teeple, and M. Gilbertson. 1983. Double-crested Cormorants of the Great Lakes: egg-laying parameters, reproductive failure and contaminant residues in eggs. Canadian Journal of Zoology 61:427-436.

Wolford, J. W. and D. A. Boag. 1971. Distribution and biology of Black-crowned Night Herons in Alberta. Canadian Field-Naturalist 85:13-19.

Wood, H. B. and M. Wood. 1933. A Pennsylvania Black-crowned Night Heron colony. Auk 50:93-94.

APPENDICES

Appendix A. Colonial tree-nesting waterbird colony locations (n=71) and nesting species observed by N. Drilling (unpub. data) within my study area of northeast South Dakota.

Colony Site	County	Species
Lake Sinai	Brookings	DCCO
Oakwood Lake – 1	Brookings	CAEG, DCCO, GBHE, GREG
Oakwood Lake – 2	Brookings	DCCO, GBHE
Twin Lakes (East)	Brookings	DCCO, GBHE
408 Ave.-108 St marsh	Brown	CAEG, SNEG
Crow Creek Ditch @ 111 St.	Brown	GBHE
Crow Creek Ditch @ 122 St.	Brown	DCCO, GBHE
East Hecla GPA	Brown	DCCO, GBHE, GREG
James River @ Hwy 12 (Bath)	Brown	DCCO, GBHE
James River, Brown/Spink Co.	Brown	DCCO, GBHE, GREG
Putney No. 3 GPA/Putney Slough	Brown	DCCO, GBHE
Renziehausen GPA	Brown	BCNH, CAEG, SNEG
Sand Lake (Sand Lake NWR)	Brown	BCNH, CAEG, DCCO
Carson Lake	Clark	DCCO
Dry Lake No. 2	Clark	DCCO, GBHE
Foxton Twp	Clark	DCCO
Lee WPA	Clark	DCCO, GBHE
Lily Lake (South End)	Clark	DCCO, GBHE
Pepper Slough	Clark	DCCO, GREG
Swan Lake GPA	Clark	DCCO, GBHE
Blythe Slough	Codington	BCNH, CAEG, DCCO, GREG, SNEG
Dry Lake	Codington	DCCO, GBHE
Goose Lake	Codington	DCCO
Nichols GPA	Codington	DCCO
Wolf Slough	Codington	DCCO, GBHE
Bitter Lake islands	Day	BCNH, CAEG, DCCO, GBHE, GREG, SNEG
Bristol	Day	DCCO
Butler	Day	DCCO, GBHE
North of Butler	Day	DCCO
Butler/Rusk Township	Day	DCCO
Goose Lake	Day	DCCO
Hazelden Springs GPA	Day	DCCO, GBHE, GREG
Holmquist Slough	Day	DCCO, GBHE
Krause Farm GPA (East)	Day	DCCO, GBHE
Krause Farm GPA (West)	Day	DCCO
Lily GPA (Middle)	Day	DCCO, GBHE
Long Lake	Day	DCCO
Mydland Pass GPA	Day	DCCO
Opitz Lake	Day	DCCO, GBHE
Reetz Lake	Day	DCCO
Schmig WPA	Day	DCCO, GBHE
Webster Twp flooded trees	Day	DCCO, GBHE
Waubay Lake	Day	DCCO
East Coteau Lake	Deuel	GBHE
Lake Farley	Grant	GBHE
Brunick WPA	Kingsbury	DCCO
Lake Albert Island GPA	Kingsbury	BCNH, CAEG, DCCO, GBHE, GREG, SNEG
Lake Thompson GPA far SE creek	Kingsbury	GBHE
Lake Thompson GPA, NE creek	Kingsbury	DCCO
Lake Thompson GPA, SE side	Kingsbury	DCCO
Twin Lakes (West)	Kingsbury	DCCO, GBHE

Appendix A. (Continued)

Colony Site	County	Species
415 Ave. east of Claremont	Marshall	DCCO, GBHE
Eden Farm	Marshall	DCCO
4 Mile Clubhouse Slough	Marshall	BCNH, DCCO, GBHE, GREG
Hauck/Schultz WPA	Marshall	DCCO, GBHE
Intersection 122 St - 434 Ave.	Marshall	DCCO
Kettle Lake	Marshall	DCCO, GBHE, GREG
Little Cottonwood Lake GPA	Marshall	DCCO, GBHE, GREG
Drywood Lake	Roberts	DCCO, GBHE
Indian Slough	Roberts	DCCO
Owl Lake	Roberts	DCCO, GBHE
Pond 101 St. @ 453 Ave.	Roberts	DCCO, GBHE, GREG
Sather Slough	Roberts	DCCO
South of Broz WPA	Roberts	DCCO
187 St flood pond	Spink	DCCO
James River @ 158 St.	Spink	DCCO
James River @ Hwy 20	Spink	DCCO, GBHE
James River near Glendale Colony	Spink	GBHE
Turtle Creek @ 181 St.	Spink	DCCO, GBHE
Turtle Creek-James Riv. Junction	Spink	GBHE
Twin Lakes	Spink	DCCO

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix B. Colonial tree-nesting waterbird colony locations and nesting species monitored in northeast South Dakota, 2008.

Colony Site	County	Species
Oakwood Lake – 1	Brookings	CAEG, DCCO, GBHE, GREG, SNEG
Twin Lakes (East)	Brookings	DCCO, GBHE
Crow Creek Ditch @ 111 St.	Brown	GBHE
Crow Creek Ditch @ 122 St.	Brown	DCCO, GBHE
East Hecla GPA	Brown	DCCO, GBHE, GREG
Carson Lake	Clark	DCCO
Dry Lake No. 2	Clark	DCCO, GBHE
Foxton Twp	Clark	DCCO, GBHE
Swan Lake GPA NW	Clark	DCCO, GBHE
Blythe Slough	Codington	BCNH, CAEG, DCCO, GREG, SNEG
Goose Lake	Codington	DCCO
Nichols GPA	Codington	DCCO
Wolf Slough GPA	Codington	DCCO, GBHE
Butler	Day	DCCO, GBHE
Hazelden Springs GPA	Day	DCCO, GBHE, GREG
Holmquist Slough	Day	DCCO, GBHE
Krause Farm GPA (East)	Day	DCCO, GBHE
Krause Farm GPA (West)	Day	DCCO
Mydland Pass GPA	Day	BCNH, DCCO, GREG
Opitz Lake	Day	DCCO, GBHE
Reetz Lake	Day	DCCO
North of Butler	Day	DCCO
Brunick WPA	Kingsbury	DCCO
Hauck/Schultz WPA	Marshall	DCCO, GBHE
Intersection 122 St - 434 Ave.	Marshall	DCCO
Kettle Lake	Marshall	DCCO, GBHE, GREG
Little Cottonwood Lake GPA	Marshall	DCCO, GBHE, GREG
Drywood Lake	Roberts	DCCO, GBHE

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix C. Colonial tree-nesting waterbird colony locations and nesting species monitored in northeast South Dakota, 2009.

Colony Site	County	Species
Lake Sinai	Brookings	DCCO
Oakwood Lake – 1	Brookings	CAEG, DCCO, GBHE, GREG, SNEG
Oakwood Lake – 2	Brookings	DCCO, GBHE, GREG
Twin Lakes (East)	Brookings	DCCO, GBHE
Crow Creek Ditch @ 122 St.	Brown	DCCO, GBHE
East Hecla GPA	Brown	DCCO, GBHE, GREG
James River, Brown/Spink Co.	Brown	DCCO, GBHE, GREG
Lily Lake (South End)	Clark	DCCO, GBHE
Pepper Slough	Clark	BCNH, CAEG, DCCO, GREG
Blythe Slough	Codington	BCNH, CAEG, DCCO, GREG, SNEG
Wolf Slough GPA	Codington	DCCO, GBHE
Hazelden Springs GPA	Day	BCNH, DCCO, GBHE, GREG
Holmquist Slough	Day	DCCO, GBHE
Krause Farm GPA (East)	Day	DCCO, GBHE
Opitz Lake	Day	DCCO
Waubay Lake	Day	DCCO
Brunick WPA	Kingsbury	DCCO
Lake Albert Island GPA	Kingsbury	DCCO, GBHE, GREG
4 Mile Clubhouse Slough	Marshall	BCNH, DCCO, GBHE, GREG,
Kettle Lake	Marshall	DCCO, GBHE, GREG
Little Cottonwood Lake GPA	Marshall	DCCO, GBHE, GREG
Drywood Lake	Roberts	DCCO, GBHE
Pond 101 St. @ 453 Ave.	Roberts	DCCO, GBHE, GREG,
James River near Glendale Colony	Spink	GBHE
Turtle Creek @ 181 St.	Spink	DCCO, GBHE

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix D. Colonial tree-nesting waterbird colony locations (n=14) and nesting species monitored in northeast South Dakota, 2008 and 2009.

Colony Site	**County**	**Species**
Oakwood Lake – 1	Brookings	CAEG, DCCO, GBHE, GREG
Twin Lakes (East)	Brookings	DCCO, GBHE
Crow Creek Ditch @ 122 St.	Brown	DCCO, GBHE
East Hecla GPA	Brown	DCCO, GBHE, GREG
Blythe Slough	Codington	BCNH, CAEG, DCCO, GREG, SNEG
Wolf Slough GPA	Codington	DCCO, GBHE
Hazelden Springs GPA	Day	BCNH, DCCO, GBHE, GREG
Holmquist Slough	Day	DCCO, GBHE
Krause Farm GPA (East)	Day	DCCO, GBHE
Opitz Lake	Day	DCCO, GBHE
Brunick WPA	Kingsbury	DCCO
Kettle Lake	Marshall	DCCO, GBHE, GREG
Little Cottonwood Lake GPA	Marshall	DCCO, GBHE, GREG
Drywood Lake	Roberts	DCCO, GBHE

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix E. Colonial tree-nesting waterbird colony site locations (n=27) where local habitat variables were measured in northeast South Dakota, 2008 – 2009.

Colony Site	County	Latitude	Longitude
Lake Sinai	Brookings	44.2738	-97.1262
Oakwood – 1	Brookings	44.4499	-96.9693
Oakwood – 2	Brookings	44.4452	-96.9592
Twin Lakes (East)	Brookings	44.2738	-97.1262
Crow Creek @ 111 St.	Brown	45.7723	-98.0695
Crow Creek @ 122 St.	Brown	45.6146	-98.1874
East Hecla GPA	Brown	45.8750	-98.1269
James River, Brown/Spink Co.	Brown	45.2467	-98.3828
Dry Lake No. 2	Clark	44.6747	-97.6413
Lily Lake (South End)	Clark	45.1464	-97.7555
Pepper Slough	Clark	45.0469	-97.6001
Blythe Slough	Codington	44.9151	-97.4265
Wolf Slough	Codington	44.8082	-97.3434
Hazelden Springs GPA	Day	45.5108	-97.4395
Holmquist Slough	Day	45.3609	-97.6375
Krause Farm (East)	Day	45.5199	-97.5009
Mydland Pass GPA	Day	45.4782	-97.6601
Opitz Lake	Day	45.5766	-97.4887
Waubay Lake	Day	45.4233	-97.3705
Brunick WPA	Kingsbury	44.3016	-97.1754
Lake Albert Island GPA	Kingsbury	44.5190	-97.1555
4 Mile Clubhouse Slough	Marshall	45.7001	-97.5073
Hauck/Schultz WPA	Marshall	45.7564	-97.4877
Kettle Lake	Marshall	45.6649	-97.5166
Little Cottonwood Lake GPA	Marshall	45.7359	-97.4447
Drywood Lake	Roberts	45.5633	-97.1973
Pond 101 St. @ 453 Ave.	Roberts	45.9173	-97.1490

Appendix F. Non-nesting site locations (n=32) where local and landscape habitat variables were measured for colonial tree-nesting waterbirds in northeast South Dakota, 2008 – 2009.

Non-nesting Site	County	Latitude	Longitude
Wagner GPA	Clark	45.1224	-97.8423
Sherwood GPA	Clark	45.0332	-97.7729
Graves WPA	Clark	45.0056	-97.7120
Begeman GPA	Clark	44.7010	-97.7149
Twin Sloughs	Clark	45.1214	-97.8135
Bailey's Lake	Clark	44.9902	-97.7612
South Side of 167 St.	Clark	44.9619	-97.5263
Warner Lake GPA	Codington	45.0150	-97.4912
PRIVCODCO	Codington	44.8878	-97.3685
GPACODCO	Codington	44.9611	-97.3942
American Game Association GPA	Codington	45.0363	-97.3003
Dry Lake near Florence	Codington	45.0394	-97.3238
Hodgins GPA	Codington	45.0227	-97.4807
Antelope Lake	Day	45.2848	-97.4778
Hauge Marsh GPA	Day	45.5632	-97.5028
Batie GPA	Day	45.3395	-97.5625
Donley WPA	Day	45.5534	-97.6009
Arneson Slough GPA	Day	45.1715	-97.3169
Lynn Lake – 1	Day	45.4508	-97.6744
Lynn Lake – 2	Day	45.4575	-97.6616
Meuer WPA	Day	45.4125	-97.7014
Slough SW of Meuer WPA	Day	45.3936	-97.7154
Bjerke Area	Deuel	44.9494	-96.7873
Lake Alice	Deuel	44.8824	-96.6272
Lake Francis GPA	Deuel	44.8180	-96.5284
Anderson WPA	Grant	45.0914	-96.5930
Baxter Slough GPA	Hamlin	44.7880	-97.3075
Rock Crandall GPA	Marshall	45.5961	-97.5016
Bonham Area GPA	Marshall	45.6985	-97.5288
Pasture NW of Maynard	Marshall	44.8235	-97.5861
Maynard	Marshall	44.8181	-97.5583
Horseshoe Lake GPA	Marshall	45.6743	-97.5275

Appendix G. Colonial tree-nesting waterbird percent colony nest success for colonies (n=28) monitored in northeast South Dakota, 2008.

Colony	Species	Nest Success
Blythe Slough	BCNH, CAEG, DCCO GREG, SNEG	70.71
Brunick WPA	DCCO	79.31
Butler	DCCO, GBHE	87.50
Carson Lake	DCCO	80.00
Crow Creek @ 111 St.	DCCO, GBHE	80.00
Crow Creek Ditch @ 122 St.	DCCO, GBHE	19.15
Dry Lake No. 2	DCCO, GBHE	2.70
Drywood Lake	DCCO, GBHE	8.89
East Hecla GPA	DCCO, GBHE, GREG	75.86
Foxton Twp	DCCO, GBHE	79.31
Goose Lake	DCCO	90.00
Hauck/Schultz WPA	DCCO, GBHE	81.25
Hazelden Springs GPA	DCCO, GBHE, GREG	49.12
Holmquist Slough	DCCO, GBHE	90.63
Intersection @ 122 St.	DCCO	66.67
Kettle Lake	DCCO, GBHE, GREG	28.57
Krause Farm GPA (East)	DCCO, GBHE	79.41
Krause Farm GPA (West)	DCCO	63.33
Little Cottonwood Lake GPA	DCCO, GBHE. GREG	47.37
Mydland Pass GPA	BCNH, DCCO, GREG	7.89
North of Butler	DCCO	78.57
Nichols GPA	DCCO	82.14
Oakwood Lake - 1	CAEG, DCCO, GBHE, GREG, SNEG	88.79
Opitz Lake	DCCO, GBHE	26.47
Reetz Lake	DCCO	53.33
Swan Lake GPA	DCCO, GBHE	61.29
Twin Lakes (East)	DCCO, GBHE	27.03
Wolf Slough	DCCO, GBHE	66.67

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix H. Colonial tree-nesting waterbird percent colony nest success for colonies (n=25) monitored in northeast South Dakota, 2009.

Colony	Species	Nest Success
Brunick WPA	DCCO	88.00
Blythe Slough	BCNH, CAEG, DCCO, GREG, SNEG	76.80
Crow Creek @ 122 St.	DCCO, GBHE	92.86
Drywood Lake	DCCO, GBHE	62.22
East Hecla GPA	DCCO, GBHE, GREG	81.48
4 Mile Clubhouse Slough	BCNH, DCCO, GBHE, GREG	75.79
Hazelden Springs GPA	BCNH, DCCO, GBHE, GREG	60.53
Holmquist Slough	DCCO, GBHE	90.32
James River @ Brown/Spink Co.	DCCO, GBHE	53.33
James River near Glendale Colony	GBHE	68.42
Kettle Lake	DCCO, GBHE, GREG	49.15
Krause Farm GPA (East)	DCCO, GBHE	83.87
Lake Albert Island GPA	DCCO, GBHE, GREG	76.83
Lake Sinai	DCCO	86.67
Little Cottonwood Lake GPA	DCCO, GBHE, GREG	69.70
Oakwood Lake - 1	CAEG, DCCO, GBHE, GREG	82.88
Oakwood Lake - 2	DCCO, GBHE. GREG	85.96
Opitz Lake	DCCO	6.67
Pepper Slough	BCNH, CAEG, DCCO, GREG	67.57
Pond 101 St. @ 453 Ave.	DCCO, GBHE, GREG	89.86
Turtle Creek @ 181 St.	DCCO, GBHE	86.67
Twin Lake (East)	DCCO, GBHE	68.57
Waubay Lake	DCCO	50.00
Wolf Slough	DCCO, GBHE	77.78
Lily Lake (South End)	DCCO, GBHE	77.50

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix I. Colonial tree-nesting waterbird percent colony fledge success for colonies (n=28) monitored in northeast South Dakota, 2008.

Colony	Species	Fledge Success
Blythe Slough	BCNH, CAEG, DCCO GREG, SNEG	63.64
Brunick WPA	DCCO	55.17
Butler	DCCO, GBHE	84.38
Carson Lake	DCCO	73.33
Crow Creek @ 111 St.	DCCO, GBHE	20.00
Crow Creek Ditch @ 122 St.	DCCO, GBHE	12.77
Dry Lake No. 2	DCCO, GBHE	0.00
Drywood Lake	DCCO, GBHE	0.00
East Hecla GPA	DCCO, GBHE, GREG	55.17
Foxton Twp	DCCO, GBHE	66.67
Goose Lake	DCCO	50.00
Hauck/Schultz WPA	DCCO, GBHE	81.25
Hazelden Springs GPA	DCCO, GBHE, GREG	42.11
Holmquist Slough	DCCO, GBHE	62.50
Intersection @ 122 St.	DCCO	30.00
Kettle Lake	DCCO, GBHE, GREG	14.29
Krause Farm GPA (East)	DCCO, GBHE	73.53
Krause Farm GPA (West)	DCCO	60.00
Little Cottonwood Lake GPA	DCCO, GBHE. GREG	38.60
Mydland Pass GPA	BCNH, DCCO, GREG	0.00
North of Butler	DCCO	64.29
Nichols GPA	DCCO	60.71
Oakwood Lake - 1	CAEG, DCCO, GBHE, GREG, SNEG	81.31
Opitz Lake	DCCO, GBHE	0.00
Reetz Lake	DCCO	50.00
Swan Lake GPA	DCCO, GBHE	45.16
Twin Lakes (East)	DCCO, GBHE	0.00
Wolf Slough	DCCO, GBHE	60.61

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix J. Colonial tree-nesting waterbird percent colony fledge success for colonies (n=25) monitored in northeast South Dakota, 2009.

Colony	Species	Fledge Success
Brunick WPA	DCCO	40.00
Blythe Slough	BCNH, CAEG, DCCO, GREG, SNEG	70.40
Crow Creek @ 122 St.	DCCO, GBHE	85.71
Drywood Lake	DCCO, GBHE	46.67
East Hecla GPA	DCCO, GBHE, GREG	69.14
4 Mile Clubhouse Slough	BCNH, DCCO, GBHE, GREG	53.68
Hazelden Springs GPA	BCNH, DCCO, GBHE, GREG	38.16
Holmquist Slough	DCCO, GBHE	67.74
James River @ Brown/Spink Co.	DCCO, GBHE	28.33
James River near Glendale Colony	GBHE	68.42
Kettle Lake	DCCO, GBHE, GREG	33.90
Krause Farm GPA (East)	DCCO, GBHE	61.29
Lake Albert Island GPA	DCCO, GBHE, GREG	51.22
Lake Sinai	DCCO	76.67
Little Cottonwood Lake GPA	DCCO, GBHE, GREG	51.52
Oakwood Lake - 1	CAEG, DCCO, GBHE, GREG	74.77
Oakwood Lake - 2	DCCO, GBHE. GREG	57.89
Opitz Lake	DCCO	0.00
Pepper Slough	BCNH, CAEG, DCCO, GREG	52.70
Pond 101 St. @ 453 Ave.	DCCO, GBHE, GREG	89.86
Turtle Creek @ 181 St.	DCCO, GBHE	73.33
Twin Lake (East)	DCCO, GBHE	34.29
Waubay Lake	DCCO	16.67
Wolf Slough	DCCO, GBHE	58.33
Lily Lake (South End)	DCCO, GBHE	47.50

Colonial tree-nesting waterbird species abbreviations, BCNH = Black-crowned night heron, GBHE = Great blue heron, CAEG = Cattle egret, GREG = Great egret, SNEG = Snowy egret, DCCO = Double-crested cormorant.

Appendix K. Local variables measured within colonies of colonial tree-nesting waterbirds in northeast South Dakota, 2008 – 2009.

Variable	**Code**
% Bare Ground Coverage	BareGr
% Cattail Coverage	Cattail
% Forb Coverage	Forb
% Grass Coverage	Grass
% "Other" Coverage	Other
% Shrub Coverage	Shrub
% Water Coverage	Water
American Elm Absolute Density	AelmDen
Boxelder Absolute Density	BoxDen
Buckthorn Absolute Density	BuckDen
Bur Oak Absolute Density	BODen
Cottonwood Absolute Density	CotDen
Eastern Redcedar Absolute Density	CedarDen
Green Ash Absolute Density	GrnAshDen
Honeylocust Absolute Density	HLDen
Ironwood Absolute Density	IronDen
Mean Herbaceous Vegetation Height (cm)	HVHt
Russian-Olive Absolute Density	RODen
Total Absolute Tree Density	TotDen
Willow spp. Absolute Density	WillowDen
Mean Tree Height (m)	TreeHt
% Dead Trees	DeadTree
% Live Trees	LiveTree
Colony Area (Ha)	ColArea
% BCNH Nests	% BCNH
% CAEG Nests	% CAEG
% DCCO Nests	% DCCO
% GBHE Nests	% GBHE
% GREG Nests	% GREG
% SNEG Nests	% SNEG
Total Nests Present	TotNest

Appendix L. Landscape variables measured surrounding colonies of colonial tree-nesting waterbirds in northeast South Dakota, 2008 – 2009.

Variable	Code
% Cultivated Crop within 400 m	Crop_400
% Cultivated Crop within 800 m	Crop_800
% Cultivated Crop within 1600 m	Crop_1600
% Cultivated Crop within 3200 m	Crop_3200
% Cultivated Crop within 6400 m	Crop_6400
% Deciduous Forest within 400 m	Dec_400
% Deciduous Forest within 800 m	Dec_800
% Deciduous Forest within 1600 m	Dec_1600
% Deciduous Forest within 3200 m	Dec_3200
% Deciduous Forest within 6400 m	Dec_6400
% Developed Area within 400 m	Dev_400
% Developed Area within 800 m	Dev_800
% Developed Area within 1600 m	Dev_1600
% Developed Area within 3200 m	Dev_3200
% Developed Area within 6400 m	Dev_6400
% Emergent Herbaceous Wetland within 400 m	HerbWet_400
% Emergent Herbaceous Wetland within 800 m	HerbWet_800
% Emergent Herbaceous Wetland within 1600 m	HerbWet_1600
% Emergent Herbaceous Wetland within 3200 m	HerbWet_3200
% Emergent Herbaceous Wetland within 6400 m	HerbWet_6400
% Evergreen Forest within 400 m	Evgr_400
% Evergreen Forest within 800 m	Evgr_800
% Evergreen Forest within 1600 m	Evgr_1600
% Evergreen Forest within 3200 m	Evgr_3200
% Evergreen Forest within 6400 m	Evgr_6400
% Grass within 400 m	Grass_400
% Grass within 800 m	Grass_800
% Grass within 1600 m	Grass_1600
% Grass within 3200 m	Grass_3200
% Grass within 6400 m	Grass_6400
% Open Water within 400 m	Open_400
% Open Water within 800 m	Open_800
% Open Water within 1600 m	Open_1600
% Open Water within 3200 m	Open_3200
% Open Water within 6400 m	Open_6400
% Total Wetlands within 400 m	TotWet_400
% Total Wetlands within 800 m	TotWet_800
% Total Wetlands within 1600 m	TotWet_1600

Appendix L. (Continued)	
Variable	**Code**
% Total Wetlands within 6400 m	TotWet_6400
% Woody Wetland within 400 m	WoodWet_400
% Woody Wetland within 800 m	WoodWet_800
% Woody Wetland within 1600 m	WoodWet_1600
% Woody Wetland within 3200 m	WoodWet_3200
% Woody Wetland within 6400 m	WoodWet_6400