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Evaluation of Survey Methods for Colonial Waterbirds at Chase Lake National Wildlife Refuge, North Dakota

Open-File Report 2020–1008

U.S. Department of the Interior
U.S. Geological Survey

Front cover. Young Little Blue Herons (*Egretta caerulea*) at Chase Lake National Wildlife Refuge, Stutsman County, North Dakota. Photograph by Lawrence D. Igl, U.S. Geological Survey.

Back cover. Adult American White Pelicans (*Pelecanus erythrorhynchos*) at Chase Lake National Wildlife Refuge, Stutsman County, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

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DAVID BERNHARDT, Secretary

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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
	Area	
square meter (m^2)	0.0002471	acre
hectare (ha)	2.471	acre
square meter (m^2)	10.76	square foot (ft^2)
hectare (ha)	0.003861	square mile (mi^2)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F = (1.8 × °C) + 32.

Abbreviations

CDT	central daylight time
df	degrees of freedom
n.d.	no date
p	probability
r_s	Spearman rank correlation coefficient
R^2	coefficient of determination
SE	standard error
sp.	species (an unspecified species within the genus)
spp.	species (applies to two or more species within the genus)
t	*t*-statistic

Evaluation of Survey Methods for Colonial Waterbirds at Chase Lake National Wildlife Refuge, North Dakota

By Lawrence D. Igl,[1] Alisa J. Bartos,[2,3] Robert O. Woodward,[1] Paulette Scherr,[2] and Marsha A. Sovada[1]

Abstract

Estimating the number of breeding pairs in a mixed-species waterbird colony is difficult because colonial waterbirds are vulnerable to human intrusion and their colonies are often in remote areas with limited access. We investigated methods to estimate the number of nests of waterbirds at a large, mixed-species colony at Chase Lake National Wildlife Refuge in south-central North Dakota. The primary goals of this study were to evaluate survey methods for shrub- and ground-nesting colonial waterbirds at Chase Lake National Wildlife Refuge and to develop protocols for estimating abundance of the different species. The specific objectives were (1) to assess visible-nest counts for ciconiiform species from the perimeter of nesting areas (hereafter, perimeter counts) and observational surveys from fixed points outside the colony to count flights of adult ciconiiforms in and out of the colony (hereafter, flightline surveys) as alternatives to within-colony counts of ciconiiform nests, and (2) to assess semiautomated, pixel-based image-analysis techniques to estimate abundance of American White Pelicans (*Pelecanus erythrorhynchos*) as an alternative to traditional manual counts from aerial photographs.

For shrub-nesting ciconiiform species, observers counted 2,259 and 1,759 active ciconiiform nests in 2012 and 2013, respectively, during within-colony counts of ciconiiform nests. Results from within-colony counts of ciconiiform nests indicated a positive relation between the number of nests and the area of the shrub subcolony for the three most common ciconiiform species and all ciconiiform species combined. The perimeter nest counts of ciconiiform nests at Chase Lake represented only 18.8 percent of the total active ciconiiform nests counted in 11 subcolonies in 2012, which was well below the recommended target of 50 percent. Although we found a positive relationship between the number of nests counted during perimeter counts and the number of nests counted during within-colony counts for the three most common ciconiiform species and all ciconiiform species combined, perimeter counts at Chase Lake were hampered by disturbance to nesting birds. Thus, we discontinued the perimeter counts before they were completed. We did not develop predictive models from these perimeter counts in 2012 because these models could be misleading due to inconsistent application of the survey methods, which likely would have provided inaccurate perimeter counts. The extent of this issue is unknown. Flightline surveys at Chase Lake documented patterns of ciconiiform activity that were unknown for this region. For the common ciconiiform species, the number of flights to and from the South Island at Chase Lake were greatest in the morning (7:00−12:00 central daylight time [CDT]) and least in the afternoon (12:00−17:00), and least early in the breeding season (May 29–June 20, 2013) and greatest later in the breeding season (June 24–August 1, 2013). Flightline surveys are an index but lacked comparability with within-colony nest counts because the two methods provide measures of different things (that is, adult activity away from the colony as compared to the number of nests within the colony). The overall proportions of flights generally reflected the proportions of the within-colony nest counts for the four most common species: Black-crowned Night-Heron (*Nycticorax nycticorax*), Cattle Egret (*Bubulcus ibis*), Great Egret (*Ardea alba*), and Snowy Egret (*Egretta thula*). Flightline surveys at Chase Lake indicated apparent variation related to the time of day and season, as well as a variation in detection of inbound and outbound adult ciconiiforms. For ciconiiforms at Chase Lake, the most appropriate combination of survey approaches will depend on the need for annual estimates of nest abundance of ciconiiform species, balanced with the financial, personnel, and logistical constraints associated with the survey methods.

For ground-nesting American White Pelicans, the results from this study indicated that digital-image processing using remote-sensing software provides an accurate estimate of the number of American White Pelican nests. Estimates of the number of pelican nests from digital-image processing, using two commercially available remote-sensing software packages, produced nest estimates that were comparable to those of traditional manual counts from aerial photographs.

[1]U.S. Geological Survey.

[2]U.S. Fish and Wildlife Service.

[3]Northern Great Plains Joint Venture (current).

Introduction

Monitoring the size and species composition of waterbird colonies is important to the management and conservation of those species. Because colonial waterbirds concentrate their nesting activities at a few sites, these species are highly vulnerable to diseases, predation, weather events, and other disturbances (Sovada and others, 2013, 2014). For colonial waterbirds, major abundance fluctuations often go undetected because surveys or censuses are not conducted regularly, inventory methods are inconsistent, or estimates have unknown reliability (Hutchinson, 1979). Moreover, colonial waterbird surveys also are challenging because entry into a colony may disturb nesting birds, colonies often are remote and difficult to access, and some colonies are very large and contain multiple species (Steinkamp and others, 2003; Baker and others, 2015; Reintsma and others, 2018).

In recent years, the waterbird colony at Chase Lake National Wildlife Refuge in south-central North Dakota has become one of the largest mixed-species waterbird colonies in the northern Great Plains and certainly one of the most important waterbird colonies administered by the U.S. Fish and Wildlife Service in this region (Sovada and others, 2005, 2013, 2014). In particular, Chase Lake is among the largest colonies of nesting American White Pelicans (*Pelecanus erythrorhynchos*) in North America (Sovada and others, 2005). Historically, American White Pelicans and other ground-nesting colonial waterbirds (Double-crested Cormorant [*Phalacrocorax auritus*], Ring-billed Gull [*Larus delawarensis*], and California Gull [*Larus californicus*]) nested on two gravel-based islands (fig. 1; Large Island and Small Island) in the northern portion of Chase Lake (Sovada and others, 2005). Not all geographic places mentioned in report are shown on figure 1.

During the past several decades, the waterbird colony at Chase Lake has changed dramatically in species composition and in overall number of nesting birds. The waterbird colony grew during a period of rapid range expansion of waterbirds in North America, especially in the northern prairie region (Naugle and others, 1996; Sovada and others, 2005; Shaffer and others, 2007; Bartos and others, 2010; Wilson and others, 2014). In 1993, rising water levels began to engulf the two historical nesting islands in Chase Lake, but new islands formed as peninsulas were cut off from the mainland (Sovada and others, 2013, 2014). As the lake more than doubled in area and the historical islands used for nesting became smaller and eventually inundated, pelicans, cormorants, and gulls shifted their nesting to three newly formed islands (fig. 1; North, Middle, and South Islands) in the southeastern portion of the lake and a mainland peninsula in the northwest. American White Pelicans flourished during this period, and their abundance grew dramatically through time (fig. 2; Sovada and others, 2005). One of the new nesting islands (South Island) contained several small and large clumps of tall shrubs (Bartos and others, 2010), a feature that was absent on the two historical nesting islands. In 1995, Cattle Egrets (*Bubulcus ibis*), a ciconiiform species, established a colony of about 20 nests in a small clump of chokecherries (*Prunus virginiana*) on the South Island (M. Sovada, unpub. data). Since 1995, ciconiiform abundance gradually grew in numbers and diversity; in due course, Great Egrets (*Ardea alba*), Snowy Egrets (*Egretta thula*), Black-crowned Night-Herons (*Nycticorax nycticorax*), Little Blue Herons (*Egretta caerulea*), Great Blue Herons (*Ardea herodias*), White-faced Ibis (*Plegadis chihi*), and Glossy Ibis (*Plegadis falcinellus*) also began nesting in the tall shrubs on the South Island. Vernacular and scientific names of plants and animals follow the Integrated Taxonomic Information System (https://www.itis.gov).

History of Waterbird Monitoring at Chase Lake

Sovada and others (2005) summarized historical and recent information on annual abundance of nesting American White Pelicans at Chase Lake. Data collection on the nesting abundance of American White Pelicans at Chase Lake during the first three-quarters of the 20th century was sporadic, the type of information collected (for example, number of adults, nests, or fledged young) was inconsistent among years, and the dates of surveys within a year were variable or not recorded (Sovada and others, 2005) (fig. 2; table 1.1). Between 1972 and 1979, biologists conducted annual surveys of pelican nests by walking through the colony and counting nests (Sovada and others, 2005). As the number of nesting pelicans increased through time, within-colony nest counts became impractical because they caused unacceptable levels of disturbance to nesting pelicans and other waterbirds. Between 1980 and 2002, the U.S. Fish and Wildlife Service, in cooperation with the U.S. Geological Survey, conducted annual nest surveys of pelican abundance at Chase Lake by manually counting visible nests on aerial photographs (Sidle and Ferguson, 1982; Sovada and others, 2005). In 2003, researchers began counting pelican nests at Chase Lake using semiautomated analysis of scanned or digital aerial photographs with remote-sensing software (fig. 2).

Compared with pelicans, information on the abundance of other waterbird species nesting at Chase Lake is limited. A few historical accounts (for example, Bennett, 1926) and refuge annual reports (Arrowwood National Wildlife Refuge, 1937–1985; Chase Lake National Wildlife Refuge, 1986–2002) included estimates of the numbers of nests or adults for some species. In 1924, Bennett (1926) noted that there were 40 California Gull nests and 160 Ring-billed Gull nests on Large Island at Chase Lake. Refuge personnel estimated that there were 300 Ring-billed Gull nests at Chase Lake in 1950 (Arrowwood National Wildlife Refuge, 1950) and 500 Ring-billed and California gull nests in 1967 (Arrowwood National Wildlife Refuge, 1967). Refuge annual narratives also indicated that there were 900 Double-crested Cormorant nests in 1963, 150 nests in 1967, 491 nests in 1970, 785 nests

Figure 1. Location of islands and peninsulas used by colonial waterbirds for nesting at Chase Lake National Wildlife Refuge, North Dakota, between 1905 and 2017.

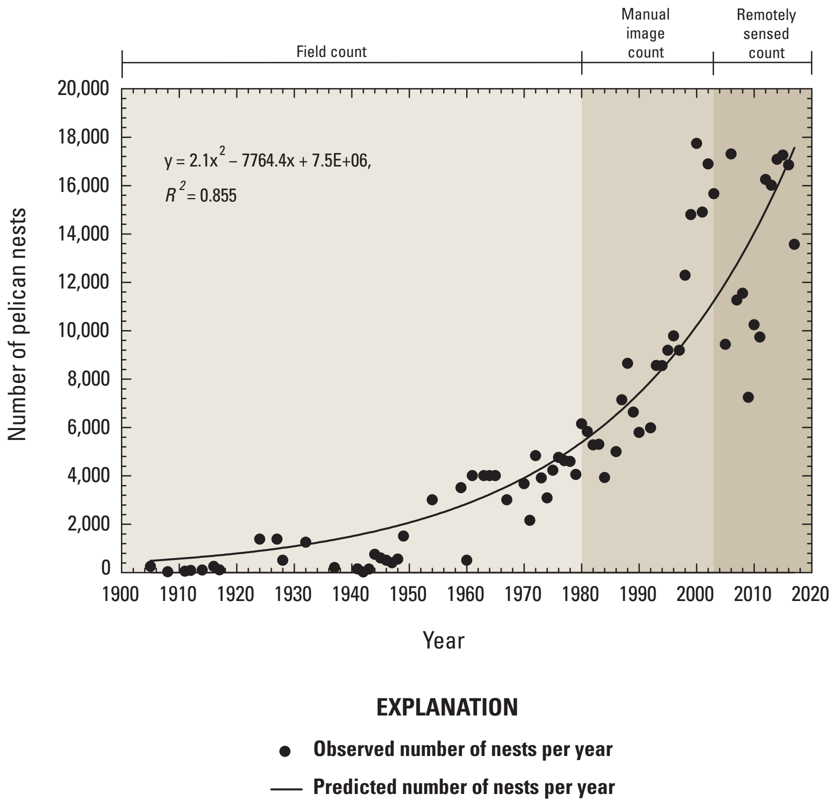

Figure 2. Abundance estimates of American White Pelicans (*Pelecanus erythrorhynchos*) at Chase Lake National Wildlife Refuge, North Dakota, based on within-colony ground counts of nests or adults (1905–71), manual counts of nests from aerial photographs (1972–2002), and remotely sensed counts of nests from aerial photographs (2003–17).

in 1983, 157 nests in 1986, 445 nests in 1987, and 353 nests in 1989 (Arrowwood National Wildlife Refuge, 1967–1983; Chase Lake National Wildlife Refuge, 1986–1989). During ground censuses of pelican nests on the Large and Small Islands at Chase Lake in 1976 and 1977, Lingle (1977) also counted nests of California Gulls (779 and 443, respectively), Ring-billed Gulls (3,347 and 3,083, respectively), and Double-crested Cormorants (746 and 469, respectively). Common Terns (*Sterna hirundo*) were mentioned as nesting at Chase Lake in several refuge reports between 1959 and 1990 (Arrowwood National Wildlife Refuge, 1959–1990), but no abundance estimates were reported, and the species has not been observed nesting at Chase Lake in recent decades. Small numbers of Caspian Terns (*Sterna caspia*) colonized the new islands in 2002 and have nested intermittently on the islands since then. In 2007, a postbreeding nest count revealed more than 1,600 ciconiiform nests (Bartos and others, 2010).

Review of Potential Survey Methods at Chase Lake

Selecting survey methods for colonial waterbirds at Chase Lake poses considerable challenges, given the colony's large size (estimated at over 25,000 breeding pairs in recent years; fig. 2), richness (greater than [>] 10 species), and status as a National Wilderness Area (Sovada and others, 2005). Steinkamp and others (2003) and Jones (2008) provided recommendations for choosing appropriate survey methods. The method(s) chosen depends on the resources and personnel available, the degree of habitat heterogeneity within the area to be surveyed, the species present, the biological characteristics of the species to be sampled, and if the surveys can be completed with an acceptable level of disturbance to nesting birds. Surveys typically are done during peak breeding activities, which depends on the breeding chronology of the species in the colony. Although disturbance is a potential issue at any waterbird colony, each waterbird species in a colony may react differently depending upon the type and proximity of the disturbance and the birds' ability to acclimate to the disturbance (Steinkamp and others, 2003; Jones, 2008). For example, American White Pelican colonies in the western portion of their breeding range are more susceptible to human disturbance by ground surveys and aircraft than pelican colonies in the eastern portion of their breeding range, leading to lower reproductive success or colony abandonment in western pelican colonies (Bunnell and others, 1981; Boellstorff and others, 1988; Anderson and King, 2005; DiMatteo and others, 2015; D.T. King, U.S. Department of Agriculture, written commun. [n.d.]).

For waterbirds nesting in dense trees or large shrubs, Steinkamp and others (2003) indicated that within-colony nest counts from the ground tend to provide the most accurate estimates of breeding abundance. However, within-colony ground-based counts may not be appropriate in some circumstances, because observers within the colony for a long period of time may create an unacceptable level of disturbance to the nesting birds. For single- or mixed-species colonies in which the nests of each species can be readily identified, a nest count after the breeding season may provide an alternative approach for estimating abundance; however, postbreeding nest counts can be inaccurate because many nests may persist from a previous breeding season and remain empty (Leukering and others, 2001; Steinkamp and others, 2003) or nests may be destroyed by wind after nesting has ceased (A. Bartos, personal observation). At Chase Lake, nests of several shrub-nesting ciconiiforms (for example, Cattle Egrets, Snowy Egrets, Little Blue Herons, and Black-crowned Night-Herons) are nearly impossible to distinguish from one another after the breeding season (fig. 3; A. Bartos, personal observation). Less-disruptive survey techniques (such as aerial surveys or manual counts using aerial photographs) also are challenging in a mixed-species colony nesting in shrubs, like Chase Lake, because of the difficulty in distinguishing similar-plumaged species (for example, white-colored egrets, dark-colored ibises and night-herons) from the air (Gibbs and others, 1988). Also, nests of ciconiiforms at Chase Lake are stratified within the tall shrubs, and only the upper layer of nests are visible from the air (R. Woodward, personal observation).

For colonies supporting multiple ciconiiform species in dense trees or shrubs whose nests cannot be readily identified after the birds have left the colony, Steinkamp and others (2003) recommended perimeter counts during the breeding season as an alternative approach for establishing breeding abundance. Perimeter counts are conducted from land- or water-based points around the perimeter of a tree or shrub colony (Jones, 2008). For colonies that cannot be surveyed from the ground or have a large proportion of nests that are not visible from the perimeter, Steinkamp and others (2003) suggested using flightline counts (that is, counting birds entering and leaving the colony from fixed observation points) to develop an index to abundance. Flightline surveys are based on the knowledge that the adult male and female take turns at the nest to incubate eggs or brood young. Flightline surveys, however, can be challenging because nest exchange rates, and thus flight rates, can vary substantially within and among days (Frederick and others, 1996).

Air-, water-, and ground-based survey methods have been used to estimate abundance of American White Pelicans and other ground-nesting waterbirds (Steinkamp and others, 2003; Jones, 2008). These birds are often sensitive to disturbances during the incubation and brood-rearing stages of their nesting cycle, and any survey method chosen for this species should consider appropriate alternatives to within-colony ground counts (Jones, 2008). Aerial surveys using fixed-wing aircraft or helicopters are commonly used to survey American White Pelicans and other ground-nesting waterbirds (for example, cormorants, gulls, and terns) (Dolbeer and others, 1997; Jones, 2008). For large colonies of ground-nesting waterbirds, like Chase Lake, estimates of abundance derived from counting nests from aerial photographs are preferred over estimates from within-colony ground counts of nests (Jones, 2008). High-resolution image scanners, digital photography, and remote-sensing software have enabled counting methods based on computerized image analysis (Jones, 2008; Descamps and others, 2011). Although semiautomated analyses of scanned or digital aerial photographs with remote-sensing software have been used to count pelican nests at Chase Lake since 2003, there have been no published comparisons of the manual counts from aerial photographs and semiautomatic counts based on image-analysis techniques.

Objectives

The primary goals of this study were to evaluate survey methods for shrub- and ground-nesting colonial waterbirds at Chase Lake National Wildlife Refuge and to develop protocols for estimating abundance of the different species. The specific objectives were (1) to assess visible-nest counts for ciconiiform species from the perimeter of nesting areas (hereafter, perimeter counts) and observational surveys from fixed points outside the colony to count flights of adult ciconiiforms in and out of the colony (hereafter, flightline surveys) as alternatives to within-colony counts of ciconiiform nests, and (2) to assess semiautomated, pixel-based image-analysis techniques to estimate abundance of American White Pelicans as an alternative to traditional manual counts from aerial photographs.

Study Area

Chase Lake National Wildlife Refuge is 19 kilometers northwest of Medina in Stutsman County, North Dakota (47°01’N, 99°27’W). The 1,797-hectare (ha) refuge is within the glaciated Missouri Coteau physiographic region (Bluemle, 2000). The Coteau is characterized by morainic, gently rolling plains interspersed with isolated wetlands, prairie pastures, hayfields, and cropland (Sovada and others, 2005). An additional 2,474 ha of State and Federal lands are adjacent to Chase Lake National Wildlife Refuge. Approximately 50 percent of the refuge consists of wetlands; the remaining area is native grasslands. Ninety-five percent (1,682 ha) of the refuge was designated as a National Wilderness Area in 1975 (Sovada and others, 2005).

Chase Lake is the largest wetland on the refuge and is a closed alkaline lake. Its water levels are sustained by local precipitation, snow melt, and the Central Dakota Aquifer System (Swanson and others, 1988; Sturgeon, 2011, 2014). Detailed overviews of the bedrock topography, bedrock geology, and groundwater resources for this region were summarized by Sturgeon (2011, 2014). Historically, two gravel-based islands (Large and Small Islands) in Chase Lake provided protected nesting areas for pelicans and other colonial waterbirds during years of normal to low water levels (fig. 1; Sovada and others, 2013). In recent years, Chase Lake has experienced a dramatic increase in its depth and surface area, inundating historical islands and creating new nesting areas where peninsulas

Figure 3. Similarity in heron and egret nests and eggs at Chase Lake National Wildlife Refuge, North Dakota. *A*, Great Egret (*Ardea alba*). *B*, Black-crowned Night-Heron (*Nycticorax nycticorax*). *C*, Snowy Egret (*Egretta thula*). *D*, Cattle Egret (*Bubulcus ibis*). Photographs by Alisa J. Bartos, U.S. Fish and Wildlife Service.

were cut off by high water and formed new islands. In those years, well-drained, gravel-based shorelines and peninsulas also have been used for nesting (fig. 1; Sovada and others, 2005). Vegetation in the areas where pelicans nest is primarily giant sumpweed (*Cyclachaena xanthiifolia*), lambsquarters (*Chenopodium album*), narrowleaf goosefoot (*Chenopodium leptophyllum*), common kochia (*Kochia scoparia*), western snowberry (*Symphoricarpos occidentalis*), smooth brome (*Bromus inermis*), and Kentucky bluegrass (*Poa pratensis*). Salt concentration in Chase Lake increases when the lake draws down (as much as 50,000 micromhos per centimeter; Sidle and Ferguson, 1982). Historically, Chase Lake did not support aquatic vertebrates because of its high salinity levels (Johnson and Sloan, 1978; Sovada and others, 2014), although some aquatic vertebrates (for example, tiger salamander [*Ambystoma tigrinum*], minnows [species unknown]) have been reported in Chase Lake in recent years under less saline conditions (Mushet and others, 2013; A. Bartos, personal observation). Brine shrimp (*Branchinecta* species [spp.] and *Artemia salina*) and water boatmen (*Cenocorixa* species [sp.]) are the most common invertebrates in Chase Lake (Sovada and others, 2005).

Part A. Ciconiiforms Nesting in Tall Shrubs

During the past decade, ciconiiforms have become an important component of the waterbird colony at Chase Lake (Bartos and others, 2010). At least eight species of herons, egrets, and ibises have nested at Chase Lake in recent years, including Black-crowned Night-Heron, Great Blue Heron, Little Blue Heron, Glossy Ibis, White-faced Ibis, Great Egret, Snowy Egret, and Cattle Egret. Most of these ciconiiforms nested in small and large clumps of tall shrubs (hereafter, shrub subcolonies) of various sizes scattered throughout the largest island (South Island) of Chase Lake (fig. 4).

One specific objective of this study was to assess perimeter nest counts in 2012 and flightline surveys in 2013 as alternatives to within-colony counts of ciconiiform nests. Perimeter counts and flightline surveys were done in association with within-colony nest counts during the breeding season to establish a relationship between the number of perimeter nests or flights and the total number of active nests in the shrub subcolonies. The full datasets used for the analyses in this objective are available as a USGS data release (Igl and others, 2020) and tables within this report.

Methods

Within-Colony Counts of Ciconiiform Nests (2012 and 2013)

Trained observers conducted two within-colony counts of nests of shrub-nesting ciconiiforms in 2012 and 2013. To facilitate conducting within-colony nest counts and perimeter counts of ciconiiform nests, prior to entering the field in 2012, we identified and determined the locations, areas, and perimeter lengths (using aerial imagery from 2011) of all shrub subcolonies (n=26) that had a history of recent nesting (past 5 years) by ciconiiforms on the South Island (fig. 4; A. Bartos, personal observation). Each shrub subcolony was given a unique alphabetic code. To reduce disturbances to nesting birds, the timing of the direct within-colony nest counts of ciconiiform nests at Chase Lake in 2012 and 2013 coincided with the period when most ciconiiform nests contained late-incubated eggs or nest-bound chicks of 1–2 weeks of age. In those years, several thousand pelicans also nested on the ground under the shrub canopies at Chase Lake (fig. 5). To avoid disturbing nesting pelicans associated with or near the shrub subcolonies, ciconiiform nests were counted after the young pelicans left their nests to form juvenile crèches, which typically begins about 17 days after pelican eggs hatch (Evans, 1984). Within-colony nest counts of ciconiiforms were done in moderate weather conditions, when it was neither too hot (>26.7 degrees Celsius [°C]) nor too cold (less than [<] 0 °C), not raining, and not excessively windy (>38 kilometers per hour). Within-colony nest counts were discontinued and completed on a subsequent date if weather conditions deteriorated during the count, if an observer deemed the disturbance level as excessive, or if most ciconiiform nests within a subcolony were at an early stage of incubation. Each count was completed by one to three observers over multiple days to minimize disturbances and the length of time observers were in a subcolony.

During the first nest count, an observer walked slowly through a shrub subcolony in a serpentine pattern to count ciconiiform nests by species. To ensure positive identification, nest identification was based on the appearance of adults or identifiable nest-bound young in a nest. We did not use relative size of the nest or placement of the nest in the canopy to distinguish species because nests of Cattle Egrets, Snowy Egrets, Little Blue Herons, and Black-crowned Night-Herons vary considerably in size and placement and are difficult to identify by nest alone (fig. 3; A. Bartos, personal observation; Frederick and others, 1996; Steinkamp and others, 2003). We also did not use eggs to distinguish these nesting species, because eggs of Great Egrets, Cattle Egrets, Snowy Egrets, Little Blue Herons, and Black-crowned Night-Herons (fig. 3) may be difficult to distinguish using egg size, color, and shape.

To avoid double-counting nests and to facilitate revisiting nests at a later date, nests that were identified to species were marked with a small dot of high visibility orange or red spray paint, and nests that were unknown (that is, contained unidentifiable eggs or hatchlings) or were empty (that is, no nest contents) were marked with a small dot of yellow spray paint. The Chase Lake colony was revisited later (that is, second count) in the breeding season to identify nests that had been marked with yellow spray paint during the first count. Nests that could be identified to species during these second counts were tallied and marked with orange or red spray paint. Nests that remained unidentifiable or empty were tallied as such and the nests were not remarked.

Most of the ciconiiform nests were built in trees over land on the island, but a small percentage (<5 percent) were in flooded shrubs over water (fig. 6). During nest counts, observers did not enter portions of subcolonies where nests were built in shrubs over water to avoid flushing chicks out of nest bowls into the water. These nests were counted visually from a boat. In 2012, a small percentage of Black-crowned Night-Herons also nested on the ground outside of the tall-shrub subcolonies in patches of short-statured shrubs (western snowberry [*Symphoricarpos occidentalis*] and poison ivy [*Toxicodendron radicans*]). These nests were counted and marked with orange or red spray paint.

Negative binomial regression models (Hilbe, 2011) were used to assess the relationship between subcolony ground counts and subcolony area for the three most common ciconiiform species (that is, Great Egret, Black-crowned Night-Heron, and Cattle Egret) and for all ciconiiforms combined in 2012−13. Models included effects for year, area, and an interaction between year and area. Year was treated as a repeated measure within each subcolony; therefore, subcolony was included in the model as a random effect. Subcolony area was

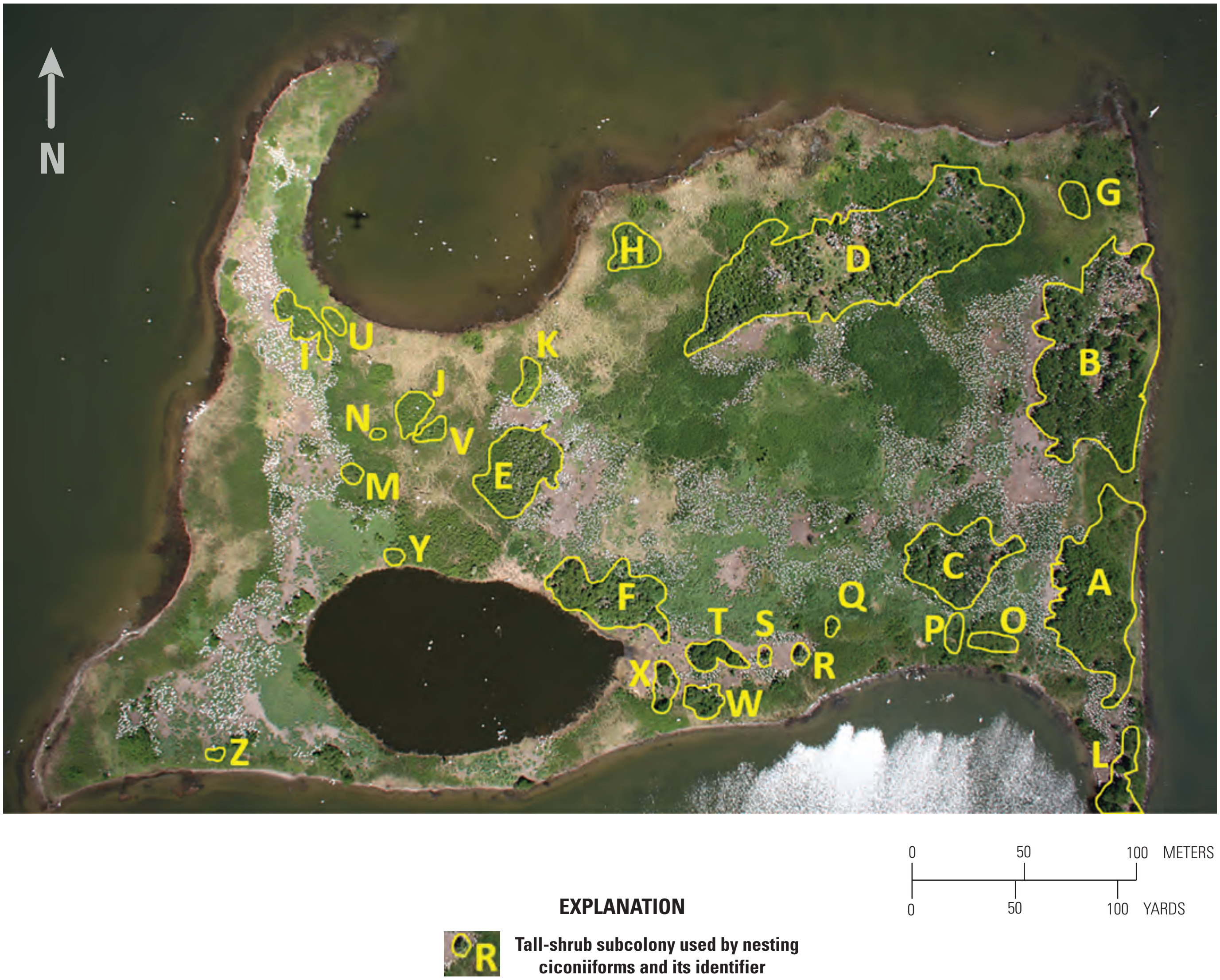

Figure 4. Locations of 26 tall-shrub subcolonies (A–Z) used by nesting ciconiiforms on the South Island of Chase Lake, North Dakota, 2012–13.

skewed with a few high values, so area was log transformed prior to analyses to reduce the effect of potential influential points. To assess model fit, the association between the observed and predicted values from the model were examined (Piñeiro and others, 2008). All models were run using PROC GLIMMIX of SAS (SAS Institute, Inc., 2017). Plots of the relationship between number of nests and subcolony area (log area) were created for each species and all ciconiiform species combined; the average prediction for the 2 years was plotted rather than the individual years.

Perimeter Counts of Ciconiiform Nests (2012)

In 2012, perimeter counts of ciconiiform nests were conducted by one to two experienced observers from island locations or occasionally from boats around the perimeter of 11 of the 26 shrub subcolonies on the South Island. For perimeter counts, Steinkamp and others (2003) recommended (1) establishing survey locations during the nonbreeding season, (2) locating survey locations around the subcolony at distances that allow birds to be counted without disturbing the nesting birds, (3) establishing unique landmarks within each subcolony to establish which nests to count from each point, and (4) counting at least 50 percent (preferably 75 percent) of the nests within each colony. To facilitate perimeter counts of ciconiiform nests, in February 2012 (that is, before ice-off on the lake and before spring arrival of nesting waterbirds), field personnel placed unique alpha-numeric markers (white livestock ear tags with black lettering) around the perimeter of the largest shrub subcolonies. Fixed survey points were then located around the perimeter of all subcolonies. The number and location of survey points varied among subcolonies based on the subcolony size and shape, the vegetation density and

Figure 5. Ground nests with American White Pelican (*Pelecanus erythrorhynchos*) chicks beneath and along the edge of tall shrubs on the South Island of Chase Lake, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

structure, and the locations of the alpha-numeric markers. The survey observation points were located at sufficient intervals around the shrub subcolonies to allow for counting the maximum number of nests and minimizing the risk of double-counting nests (Jones, 2008). All observation points were between 25 and 50 meters (m) from the edge of a subcolony.

To facilitate nest identification during perimeter counts, observers should not flush adults from their nests. Jones (2008) indicated that perimeter counts can be conducted during any time of the day and during any nesting stage. Perimeter nest counts at Chase Lake were conducted in moderate weather conditions, when it was neither too hot (>26.7 °C) nor too cold (<0 °C), not raining, and not excessively windy (>38 kilometers per hour). Perimeter counts took place when most nests were in the early to mid-incubation stage, when at least one adult was present at a nest. The timing of spring arrival, clutch initiation, and incubation varies from year to year; the initiation of the perimeter counts in 2012 was based on observations of breeding behavior of ciconiiforms from the mainland or a boat. We selected the incubation stage over the nestling stage, because the branching behavior (that is, climbing into branches near their nests) of young ciconiiforms can make it difficult to assign species to a given nest (Rodgers and others, 2005; Green and others, 2008). The timing of the perimeter counts (that is, during early to mid-incubation stage) did not overlap with the timing of the within-colony total nest counts (that is, late-incubation stage to early nestling stage). For land-based points, observers used camouflaged blinds with mirrored panels (GhostBlind Industry, Inc., Marietta, Ohio) and camouflaged clothing and face masks to conceal their location from nesting birds. We also evaluated the birds' responses to observers wearing white Tyvek® suits. For observation points from boats, observers anchored the boat at an observation point and counted the number of nests by species between target points. Observers assigned one of four codes (poor, fair, good, or excellent) to describe the count quality of each perimeter count for each species based on environmental conditions (for example, shrub density

Figure 6. Great Egret (*Ardea alba*) nests in flooded shrubs on the South Island at Chase Lake National Wildlife Refuge, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

and weather), ciconiiform behavior (for example, mobility of chicks), and disturbance to ciconiiforms and other nesting waterbirds (for example, pelicans, cormorants, and gulls) at the time of the perimeter count. Perimeter counts were discontinued if weather conditions deteriorated during the count or if an observer deemed the disturbance level as excessive. If a perimeter count was repeated at a later date or by another observer, we used the maximum number of nests identified at an observation point. Perimeter counts were not initiated at an observation point if an observer deemed the disturbance level as excessive at the beginning of the count.

We used Spearman rank correlation coefficients (SAS Institute, Inc., 2017) to assess the relationship between the perimeter counts and total nest counts in the 11 subcolonies for the three most common species (Black-crowned Night-Heron, Great Egret, and Cattle Egret) and all ciconiiform species combined.

Flightline Survey of Adult Ciconiiforms (2013)

Because of Chase Lake's high salinity, in most years, the lake does not support fish or other aquatic vertebrates, such as tiger salamanders (Sovada and others, 2005), which are important food items in the diets of colonial-nesting waterbirds, including pelicans, cormorants, herons, egrets, and ibises (Ohlendorf and others, 1974, 1979). As a result, most colonial waterbirds nesting on islands at Chase Lake forage elsewhere in nearby or distant wetlands (Sovada and others, 2005).

Steinkamp and others (2003) indicated that flightline surveys should be used as an index of abundance for waterbird colonies (1) that cannot easily be surveyed from within the colony, (2) that have a large proportion of nests that are not visible from the perimeter, (3) that have dark-colored species that would be poorly detected by aerial or perimeter surveys, or (4) when disturbances caused by colony entry are unacceptable. Flightline surveys are used to index to the abundance of ciconiiforms in colonies by counting flights of adult ciconiiforms exiting (outbound) or entering (inbound) the nesting colony. This method was developed to address the challenges of counting similar-plumaged species, well-concealed nests within dense vegetation, and research-related disturbances by shifting the focus from counting nests to counting birds that are exiting (outbound) or entering (inbound) the nesting colony (Erwin and Ogden, 1980; Erwin, 1981; Steinkamp and others, 2003; Cox and others, 2017). The method requires monitoring the number of adults flying to and from nesting colonies over a period of one to several hours within a day across the breeding season. The main advantage of flightline surveys is the possibility of recording a large sample without disturbing the nesting birds. The method is useful for small colonies but may be less useful for large colonies (Erwin, 1981; Jones, 2008), such as the colony at Chase Lake.

In preparation for flightline surveys in 2013, three observation points were established in 2012 in the upland grasslands on the south and southeast sides of Chase Lake. These points encompassed the busiest flight corridors or pathways used by ciconiiforms and other waterbirds entering and exiting the South Island (A. Bartos, personal observation). Observations in previous years indicated that most colonial-nesting waterbirds at Chase Lake left the South Island in southerly directions and most inbound birds approached the island from southerly directions. The observation points were elevated and provided an unobstructed view for observing the greatest number of ciconiiforms entering and leaving the colony (fig. 7). Flightline surveys began at least 1 hour after sunrise (Erwin and Ogden, 1980; Erwin, 1981; Cox and others, 2017) to preclude counting roosting birds, which typically leave a nesting colony near dawn, and to capture the nest exchanges between incubating or nest-guarding adults in the morning. Flightline surveys began on May 29, 2013, when most species were incubating. A flightline survey was terminated when weather conditions became inclement (for example, rain, strong winds [>38 kilometers per hour], or lightning). Surveys were discontinued after August 1 because it became increasingly difficult for observers to separate adults from young birds that could fly and were engaged in foraging flights. Multiple observers typically are recommended for simultaneous flightline surveys of large colonies (Erwin and Ogden, 1980; Erwin, 1981), such as Chase Lake, but we used a single observer because of logistical challenges and constraints associated with concurrent work and the number of available observers.

Inbound and outbound birds were counted separately. Flightline survey data were summarized as the number of adults observed flying per hour; mean flight rates across time and date were used to compare with within-colony nest counts from the ground (Erwin and Ogden, 1980). We summarized the flightline surveys by inbound, outbound, and total (inbound and outbound combined) flight rates (average number of flights per hour) by 1-hour time periods and by survey dates. For the four most common species (Great Egret, Cattle Egret, Snowy Egret, Black-crowned Night-Heron), linear regressions were generated for total flight rates by time period and by date using SigmaPlot® version 13.0 (Systat Software Inc., Richland, California). The average flight rates of inbound and outbound flights for the common species were compared using paired *t*-tests. We also calculated the proportion of total flights for the four common species by dividing the individual species' flight rate by the total flight rate for all ciconiiform species combined; this was done for morning (7:00–12:00 CDT) and afternoon (12:00–17:00) flights and early (May 29–June 20, 2013) and late (June 24–August 1, 2013) season flights.

Results

Within-Colony Counts of Ciconiiform Nests (2012 and 2013)

In 2012 and 2013, observers completed within-colony nest counts of ciconiiform nests in 26 shrub subcolonies on the South Island at Chase Lake (tables 1 and 2). The area of the 26 shrub subcolonies varied from 50 to 6,991 square meters and averaged 772 square meters. Perimeter length of individual subcolonies varied from 26 to 457 m and averaged 93 m.

In 2012, observers completed the first within-colony counts of ciconiiform nests in 27.7 hours spread across 11 days between June 22 and July 10. On average, an observer spent 2.5 hours (range 1.0–3.9 hours) during a visit implementing a first within-colony count; first counts were completed between 7:24 and 13:30 CDT. The second within-colony count were completed over 5 days between July 19 and August 6, 2012; during this second count, observers attempted to identify nests that had not been identified during the first ground count. On average, an observer spent 1.1 hours (range 0.6–1.6 hours) on the second ground count; second counts were completed between 9:43 and 11:45 CDT. In 2012, observers counted 2,259 active ciconiiform nests of six species in 25 of the 26 shrub subcolonies, including 835 Black-crowned Night-Heron nests, 723 Cattle Egret nests, 470 Great Egret nests, 45 Snowy Egret nests, 3 Great Blue Heron nests, and 1 Little Blue Heron nest (table 1). No ciconiiform nests were found in subcolony N (table 1). Observers also counted 182 active nests that could not be identified to species, and 588 nests that were empty during the first and second counts. The number of active nests per subcolony averaged 85.6 nests and varied from 0 to 494 nests. Thirty-four Black-crowned Night-Heron nests also were counted on the ground around the perimeter of the tall-shrub subcolonies in patches of western snowberry and poison ivy. Observers also counted 3,069 nests of American White Pelicans under the shrub canopy of the subcolonies in 2012 (fig. 5).

In 2013, observers completed the first within-colony counts of ciconiiform nests in 34.6 hours spread across 10 days between June 24 and August 26. On average, an observer spent 3.5 hours (range 2.6–3.9 hours) during a visit implementing a first count; first counts were completed between 6:45 and 14:27 CDT. A second within-colony count were completed over 7 days between August 6 and 22, 2013;

Figure 7. U.S. Fish and Wildlife Service scientist conducting a flightline survey of ciconiiform species from an unobstructed view on the south side of Chase Lake, North Dakota, 2013. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

during this second count, observers attempted to identify nests not identified during the first within-colony count. On average, an observer spent 3.1 hours (range 1.5–4.3 hours) during a visit implementing a second within-colony count; second counts were completed between 7:06 and 11:36 CDT. In 2013, observers counted 1,759 active ciconiiform nests of four species in 21 of the 26 shrub subcolonies, including 562 Black-crowned Night-Heron nests, 557 Cattle Egret nests, 419 Great Egret nests, and 18 Snowy Egret nests (table 2). No ciconiiform nests were found in subcolonies H, M, N, U, and V (table 2). Observers also counted 203 active nests that could not be identified to species and 1,625 nests that were empty during either the first or second counts. The number of active nests per subcolony averaged 65.1 nests and varied from 0 to 381 nests. Great Blue Herons (May 6, 2013), Little Blue Herons (June 11, 2013), Glossy Ibis (June 3 and 7, 2013), White-faced Ibis (June 3, 2013), and a possible immature White Ibis (*Eudocimus albus*; June 17 and 20, 2013) also were recorded near the colony during flightline surveys or other research activities, but no nests of these five species were counted during the first or second within-colony nest counts in 2013. Observers also counted 3,936 pelican nests under the shrub canopy of the subcolonies in 2013 (fig. 5).

The results of the negative binomial regression models assessing the relationship between the number of nests and subcolony area indicated that there was a positive relationship for Black-crowned Night-Heron (average count= $e^{-0.838+(0.6304)\text{ log of area}}$), Cattle Egret (average count= $e^{-6.91+(1.429)\text{log of area}}$), Great Egret (average count= $e^{-6.638+(1.353)\text{log of area}}$), and all ciconiiform species (average count= $e^{-1.962+(0.951)\text{log of area}}$) (fig. 8). That is, the number of nests increased as the area of subcolony increased for the three species and all ciconiiform species combined. Model fit was acceptable for Black-crowned Night-Heron, Great Egret, and all ciconiiform species combined, but model fit was poor for Cattle Egret.

Table 1. Estimates of the number of ciconiiform nests based on within-colony counts and perimeter length and area of 26 tall-shrub subcolonies on the South Island at Chase Lake National Wildlife Refuge, North Dakota, 2012.

[BCNH, Black-crowned Night-Heron (*Nycticorax nycticorax*); CAEG, Cattle Egret (*Bubulcus ibis*); GREG, Great Egret (*Ardea alba*); SNEG, Snowy Egret (*Egretta thula*); GBHE, Great Blue Heron (*Ardea herodias*); LBHE, Little Blue Heron (*Egretta caerulea*); Unknown, nest species could not be identified; Empty, nest contained no adults, eggs, or nestlings; Total occupied, total number of occupied nests, excluding empty nests; m, meter; m^2, square meter; --, no data]

Subcolony	BCNH	CAEG	GREG	SNEG	GBHE	LBHE	Unknown	Empty	Total occupied	Perimeter (m)	Area (m^2)
A	54	66	23	9	0	0	0	64	152	256	2,631
B	142	174	102	7	1	1	67	75	494	296	4,174
C	27	57	36	1	1	0	2	56	124	161	1,197
D	107	56	168	13	0	0	35	114	379	457	6,991
E	55	60	67	4	0	0	5	56	191	139	1,004
F	117	206	29	7	0	0	42	142	401	135	1,057
G	11	0	1	1	0	0	0	0	13	50	176
H	6	0	7	0	0	0	0	0	13	57	162
I	33	1	13	0	0	0	0	0	47	61	189
J	25	30	14	1	0	0	10	31	80	50	164
K	14	7	3	0	0	0	10	7	34	68	230
L	51	0	0	0	0	0	0	0	51	107	685
M	9	0	1	0	1	0	0	0	11	34	84
N	0	0	0	0	0	0	0	0	0	26	50
O	15	10	2	0	0	0	5	14	32	58	174
P	29	3	0	0	0	0	0	5	32	41	83
Q	31	1	0	0	0	0	0	0	32	31	56
R	0	0	2	0	0	0	0	2	2	36	68
S	7	0	1	0	0	0	0	0	8	31	63
T	22	44	0	1	0	0	5	14	72	71	243
U	8	0	0	0	0	0	0	0	8	42	112
V	4	0	0	0	0	0	1	1	5	41	105
W	10	6	1	1	0	0	0	6	18	56	151
X	8	0	0	0	0	0	0	0	8	51	120
Y	11	0	0	0	0	0	0	0	11	28	50
Z	5	2	0	0	0	0	0	1	7	28	58
Ground	34	0	0	0	0	0	0	0	34	--	--
Total	835	723	470	45	3	1	182	588	2,259	2,411	20,077

Table 2. Estimates of the number of ciconiiform nests based on within-colony counts and perimeter lengths and areas of 26 tall-shrub subcolonies on the South Island at Chase Lake National Wildlife Refuge, North Dakota, 2013.

[BCNH, Black-crowned Night-Heron (*Nycticorax nycticorax*); CAEG, Cattle Egret (*Bubulcus ibis*); GREG, Great Egret (*Ardea alba*); SNEG, Snowy Egret (*Egretta thula*); GBHE, Great Blue Heron (*Ardea herodias*); LBHE, Little Blue Heron (*Egretta caerulea*); Unknown, nest species could not be identified; Empty, nest contained no adults, eggs, or nestlings; Total occupied, total number of occupied nests, excluding empty nests; m, meter; m^2, square meter; --, no data]

Subcolony	BCNH	CAEG	GREG	SNEG	GBHE	LBHE	Unknown	Empty	Total occupied	Perimeter (m)	Area (m^2)
A	18	75	23	2	0	0	0	356	118	256	2,631
B	100	145	130	6	0	0	0	110	381	296	4,174
C	7	17	38	0	0	0	59	102	121	161	1,197
D	86	49	160	4	0	0	17	470	316	457	6,991
E	0	5	21	1	0	0	5	97	32	139	1,004
F	100	174	25	5	0	0	62	115	366	135	1,057
G	15	0	1	0	0	0	0	9	16	50	176
H	0	0	0	0	0	0	0	0	0	57	162
I	10	0	0	0	0	0	5	0	15	61	189
J	3	2	7	0	0	0	4	164	16	50	164
K	16	2	6	0	0	0	1	17	25	68	230
L	40	4	0	0	0	0	40	0	84	107	685
M	0	0	0	0	0	0	0	0	0	34	84
N	0	0	0	0	0	0	0	0	0	26	50
O	10	14	1	0	0	0	0	20	25	58	174
P	28	28	0	0	0	0	1	71	57	41	83
Q	26	0	0	0	0	0	0	10	26	31	56
R	1	0	1	0	0	0	0	2	2	36	68
S	13	0	2	0	0	0	1	4	16	31	63
T	54	42	4	0	0	0	6	56	106	71	243
U	0	0	0	0	0	0	0	0	0	42	112
V	0	0	0	0	0	0	0	0	0	41	105
W	6	0	0	0	0	0	0	3	6	56	151
X	10	0	0	0	0	0	1	10	11	51	120
Y	0	0	0	0	0	0	1	4	1	28	50
Z	19	0	0	0	0	0	0	5	19	28	58
Ground	0	0	0	0	0	0	0	0	0	--	--
Total	562	557	419	18	0	0	203	1,625	1,759	2,411	20,077

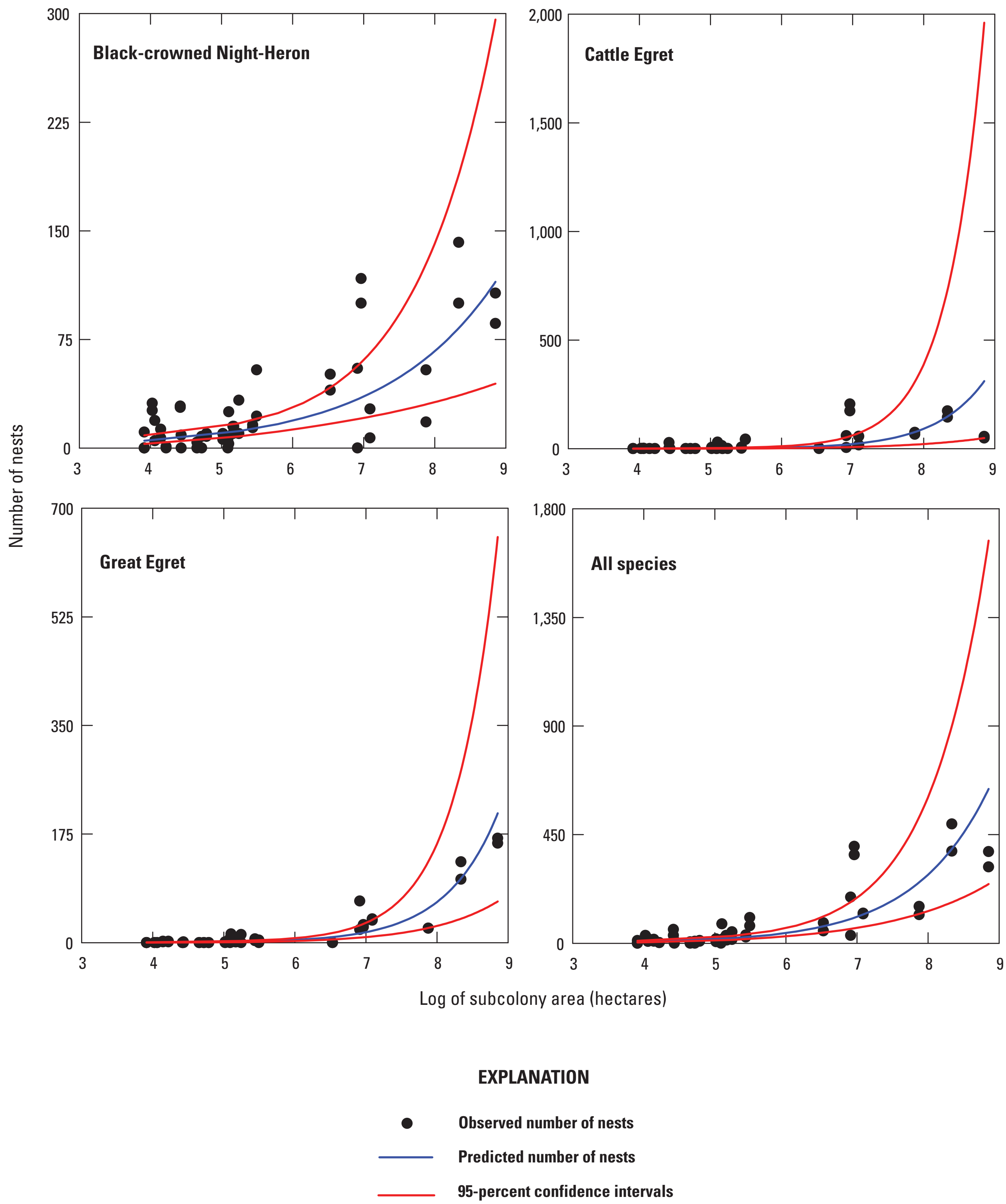

Figure 8. Relationship between subcolony area and within-colony counts (averaged across 2 years, 2012 and 2013) of Black-crowned Night-Heron (*Nycticorax nycticorax*), Cattle Egret (*Bubulcus ibis*), Great Egret (*Ardea alba*), and all ciconiiform species combined at Chase Lake National Wildlife Refuge, North Dakota.

Perimeter Counts of Ciconiiform Nests (2012)

Observers conducted perimeter counts of active ciconiiform nests visible at 11 subcolonies (A–K; fig. 4) over 27.2 hours on 9 days between May 14 and June 15, 2012. On average, an observer spent 1.35 hours (range 0.2–3.4 hours) during a visit implementing a perimeter count; perimeter counts were completed between 9:59 and 15:07 CDT. The median quality of the perimeter counts was poor, based on observers' assessments of environmental conditions, ciconiiform behavior, and disturbances to ciconiiforms and other nesting waterbirds at the time of the perimeter count (table 3). Many ciconiiforms and other waterbirds flushed from their nests when the observer approached within 50 m of the perimeter of a subcolony. Perimeter counts were not attempted at the other 15 subcolonies; the perimeter nest counts were discontinued after June 15, 2012, due to unacceptable disturbances to nesting birds.

In the 11 subcolonies that were surveyed, observers identified 362 visible ciconiiform nests of five species, including 64 Black-crowned Night-Heron nests, 42 Cattle Egret nests, 245 Great Egret nests, 6 Great Blue Heron nests, and 5 Snowy Egret nests. These nest counts represented 18.8 percent of the 1,928 active ciconiiform nests counted in these 11 subcolonies during the within-colony nest counts in that same year; the percentage of nests identified in individual subcolonies varied from 10 to 62 percent (fig. 9). There was a strong positive relationship between the number of nests counted during perimeter counts and the number of active nests counted during within-colony counts for Black-crowned Night-Heron (Spearman rank correlation [r_S]=0.76), Great Egret (r_S=0.96), Cattle Egret (r_S=0.90), and all ciconiiform species combined (r_S=0.95) (fig. 10). The number of nests counted during perimeter counts also was highly correlated with the area of the shrub subcolonies for Black-crowned Night-Heron (r_S=0.66), Great Egret (r_S=0.68), Cattle Egret (r_S=0.52), and all ciconiiforms combined (r_S=0.82).

Table 3. Quality of perimeter nest counts at individual observation points for four common ciconiiform species, based on observers' assessment of environmental conditions, ciconiiform behavior, and disturbance to ciconiiforms and other nesting waterbirds at the time of perimeter counts at Chase Lake National Wildlife Refuge, North Dakota, 2012.

[BCNH, Black-crowned Night-Heron (*Nycticorax nycticorax*); CAEG, Cattle Egret (*Bubulcus ibis*); GREG, Great Egret (*Ardea alba*); SNEG, Snowy Egret (*Egretta thula*); GBHE, Great Blue Heron (*Ardea herodias*)]

Count quality	BCNH	CAEG	GREG	SNEG	GBHE
Poor	17	12	12	7	2
Fair	1	1	4	0	1
Good	0	0	1	0	0
Excellent	0	0	0	0	0

Flightline Survey of Adult Ciconiiforms (2013)

On 26 days between May 29 and August 1, 2013, observers completed 185.9 hours of flightline surveys between 7:00 and 17:00 CDT (tables 4 and 5). On average, observers spent 3.5 hours (range 1–7 hours) during an observation implementing a flightline survey. Observers recorded 22,719 individuals of six species of ciconiiforms, including Black-crowned Night-Heron, Glossy Ibis, White-faced Ibis, Great Egret, Snowy Egret, and Cattle Egret. A small percentage (3.2 percent) of the total number of flights could not be identified to species. Overall, the number of inbound flights (9,292 birds) was lower than the number of outbound flights (13,427 birds); this variation was apparent in the flight rates (average number of flights per hour) for all four common ciconiiform species (tables 4 and 5).

The number of flights was highest in the morning and declined throughout the day for the Great Egret (coefficient of determination [R^2]=0.07, p=0.023), Black-crowned Night-Heron (R^2=0.17, p<0.001) and Snowy Egret (R^2=0.04, p=0.001), although the relationships were weak (fig. 11). Cattle Egrets (R^2=0.007, p=0.451) did not show a significant linear relationship between time and number of flights. For the ten 1-hour time periods, the average number of inbound flights was significantly lower than the average number of outbound flights for the Great Egret (14.5 plus or minus [±] 1.2 standard error [SE] versus 19.4±1.4 SE; paired t-test: t=−4.41, degrees of freedom [df] = 9, p=0.002), Cattle Egret (15.9±0.87 SE versus 23.2±1.1 SE; t=−11.09, df=9, p less than or equal to [≤] 0.001), Snowy Egret (0.7±0.11 SE versus 1.8±0.2 SE; t=−7.10, df=9, p≤0.001), Black-crowned Night-Heron (14.3±4.5 SE versus 16.7±5.3 SE; t=−5.42, df=9, p≤0.001), and all ciconiiform species combined (48.2±6.2 SE versus 84.0±9.4 SE; t=−8.03, df=9, p≤0.001) (table 4).

The number of flights was lowest early in the breeding season and increased as the breeding season progressed for the Great Egret (R^2=0.25, p<0.001), Cattle Egret (R^2=0.28, p<0.0001), and Black-crowned Night-Heron (R^2=0.13, p<0.001), but not for the Snowy Egret (R^2=0.002, p=0.65) (fig 12). The average number of inbound flights by survey dates was significantly lower than the average number of outbound flights by survey dates for the Great Egret (12.0±1.9 SE versus 16.8±2.0 SE; paired t-test: t=−2.96, df=25, p=0.007), Cattle Egret (13.4±2.4 SE versus 26.7±4.5 SE; t =−5.18, df=25, p≤0.001), Snowy Egret (0.7±0.2 SE versus 1.7±0.3 SE; t =−3.00, df=25, p≤0.006), Black-crowned Night-Heron (12.3±2.6 SE versus 18.8±3.0 SE; t =−4.87, df=25, p≤0.001), and all ciconiiform species combined (40.1±6.3 SE versus 60.4±6.5 SE; t =−4.65, df=25, p≤0.001) (table 5).

Species composition of total active nests for the four common species was similar to that of total flightline counts (table 6): Great Egret (23.4 percent of active nests versus 29 percent of flightline counts, respectively), Cattle Egret (31.7 percent versus 33.0 percent), Black-crowned Night-Heron (31.9 percent versus 32.5 percent), and Snowy Egret (1.0 percent versus 2.1 percent), indicating that flightline

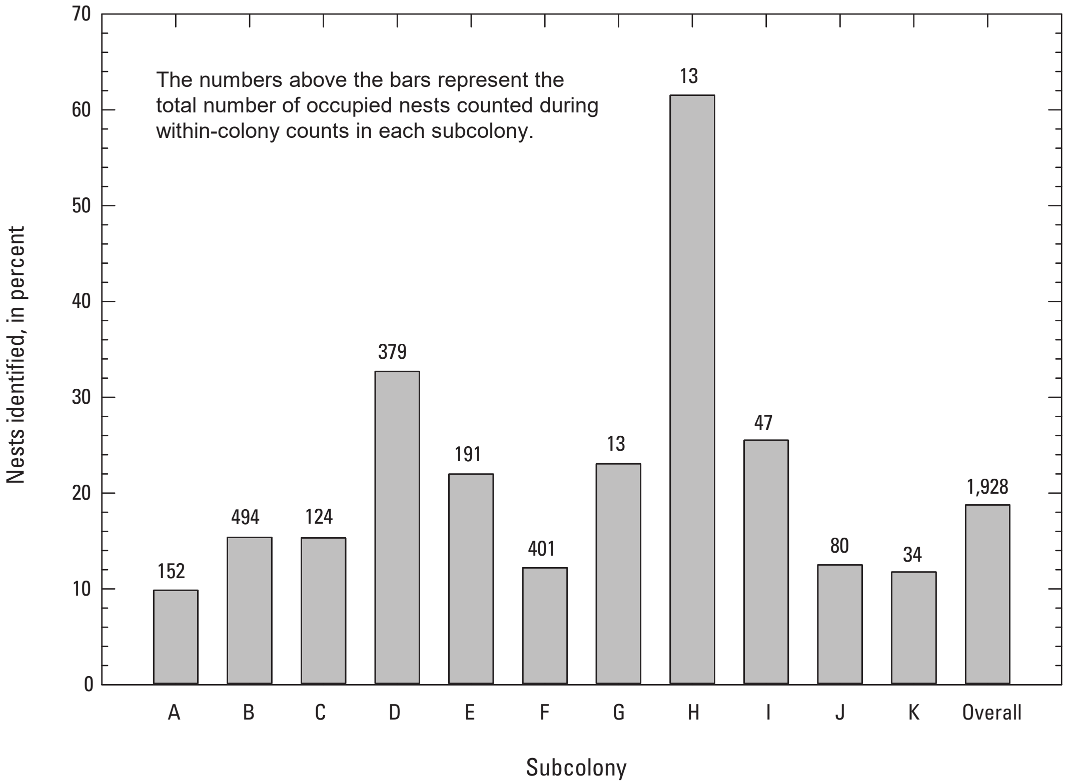

Figure 9. Percentage of heron and egret nests identified to species in 11 tall-shrub subcolonies during perimeter counts on the South Island at Chase Lake National Wildlife Refuge, North Dakota, 2012.

counts, averaged across dates and times, reflected patterns in the total numbers of nests on the South Island. The patterns between the number of active nests and flight rates varied by species between morning (07:00–12:00 CDT) and afternoon (12:00–1700) flights and between early season (May 29–June 20, 2013) and late season (June 24–August 1, 2013) flights (table 6). For example, the flight rates for the Great Egret and the Black-crowned Night-Heron were higher in the morning than in the afternoon. The proportion of all nests for these two species was closer to the proportion of all morning flight rates than afternoon flight rates for these two species (table 6). Flight rates for the Great Egret, Cattle Egret, and Black-crowned Night-Heron were over twice as high in the late season than in the early season.

Discussion

Steinkamp and others (2003) indicated that within-colony nest counts during the breeding season provide the most accurate estimate of the numbers of colonial ciconiiform nests in trees and large shrubs. During within-colony nest counts, observers counted 2,259 and 1,759 active ciconiiform nests in 2012 and 2013, respectively. Colonies of shrub-nesting ciconiiforms of this size are generally considered large (Jones, 2008). Our results indicated a positive relationship between the number of ciconiiform nests and the area of the shrub subcolony for the three most common ciconiiform species and all ciconiiform species combined, indicating that as the size of the shrub subcolony increased, the number of ciconiiform nests increased.

Results from within-colony nest surveys at Chase Lake indicated the potential for great interannual variability in the number of empty nests, at least between some years (20.6 percent of 2,847 nests in 2012 and 48.2 percent of 3,377 nests in 2013). This interannual variability supports the notion that within-colony counts of nests during the postbreeding season (that is, after the birds had departed the colony) would be inaccurate for estimating abundance of breeding adults in a colony. The large number of empty nests in some years may, in part, reflect that many nests persisted from a previous breeding season and remained empty (Rocky Mountain Bird Observatory, 2001; Steinkamp and others, 2003). Because we delayed our first within-colony nest surveys until late June to reduce disturbances to nesting pelicans, it is possible that some ciconiiform nests that were counted as empty could have been active earlier in the breeding season. It also is possible that ciconiiforms that failed at nesting did not attempt to renest at the Chase Lake colony. Steinkamp and others (2003) suggested that the nesting stage and timing during which to conduct counts should be determined based on the nesting habitat and the species present. Within-colony counts can be difficult and may be disruptive to nesting birds if the counts are poorly timed (Werschkul and others, 1976; Tremblay and Ellison, 1979; Earnst and others, 1998; Frederick and others, 1996). As such, within-colony nest surveys at Chase Lake were done only when the level of disturbance was deemed acceptable by an experienced observer.

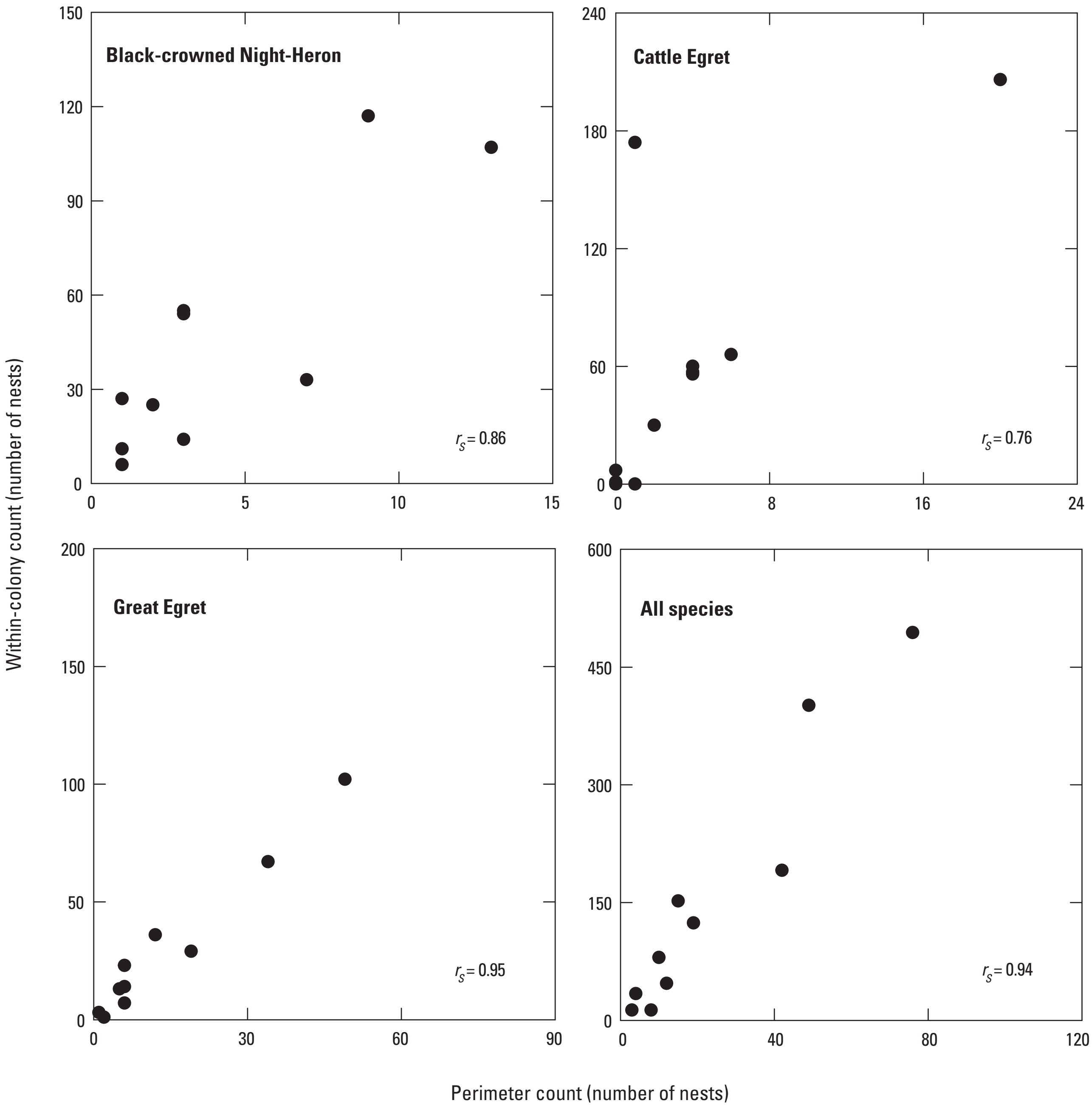

Figure 10. Relationship between perimeter counts and within-colony counts for the Black-crowned Night-Heron (*Nycticorax nycticorax*), Cattle Egret (*Bubulcus ibis*), Great Egret (*Ardea alba*), and the three species combined at Chase Lake National Wildlife Refuge, North Dakota, 2012.

Table 4. Comparison of flight rates (average number of flights per hour) among 1-hour time periods (central daylight time) for Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis)*, Snowy Egret (*Egretta thula*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and all ciconiiform species combined at Chase Lake National Wildlife Refuge, North Dakota, 2013.

Time	Hours surveyed	Great Egret			Cattle Egret			Snowy Egret			Black-crowned Night-Heron			All ciconiiforms combined[a]		
		In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
7:00–8:00	17.0	22.6	23.6	46.2	13.6	22.4	36.0	0.9	3.9	4.8	36.6	44.7	81.3	83.0	104.9	187.9
8:00–9:00	21.0	20.2	23.3	43.5	17.0	24.9	41.9	1.1	2.0	3.1	35.5	41.9	77.3	95.3	117.6	212.9
9:00–10:00	16.5	16.8	25.4	42.2	18.4	30.1	48.5	0.8	2.6	3.4	31.5	44.3	75.8	76.9	115.9	192.8
10:00–11:00	16.8	13.1	25.0	38.1	15.2	21.7	36.9	1.5	2.9	4.4	16.9	32.4	49.4	51.1	89.9	141.0
11:00–12:00	16.0	14.8	22.3	37.1	19.8	26.3	46.1	1.3	2.3	3.6	9.6	19.8	29.3	67.3	93.1	160.4
12:00–13:00	19.0	10.8	16.6	27.4	13.0	21.9	34.9	1.0	1.9	2.9	6.1	11.6	17.7	39.4	65.2	104.6
13:00–14:00	24.3	8.7	12.5	21.2	11.5	17.5	29.0	0.7	2.1	2.8	4.9	10.6	15.5	31.4	50.5	81.9
14:00–15:00	20.0	11.4	14.7	26.1	12.3	21.0	33.3	0.6	2.3	2.9	3.2	7.0	10.2	30.5	47.1	77.6
15:00–16:00	18.3	12.5	14.8	27.3	15.3	19.6	34.9	0.3	2.5	2.8	5.4	8.5	13.9	34.9	47.7	82.6
16:00–17:00	17.0	12.5	16.3	28.8	16.3	21.0	37.3	0.6	2.0	2.6	8.1	13.8	21.8	36.8	50.3	87.1
Overall	185.9	14.1	19.1	33.2	15.0	22.4	37.4	0.9	2.4	3.3	16.9	24.7	41.6	54.7	78.2	132.9

[a]All ciconiiforms combined, including Great Egret, Cattle Egret, Snowy Egret, Black-crowned Night-Heron, Great Blue Heron (*Ardea herodias*), White-faced Ibis (*Plegadis chihi*), Glossy Ibis (*Plegadis falcinellus*), and unidentified ciconiiforms.

Table 5. Comparison of flight rates (average number of flights per hour) among dates for Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*), Snowy Egret (*Egretta thula*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and all ciconiiform species combined at Chase Lake National Wildlife Refuge, North Dakota, May–August 2013.

Date	Hours surveyed	Great Egret			Cattle Egret			Snowy Egret			Black-crowned Night-Heron			All ciconiiforms combined[a]		
		In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total	In	Out	Total
May 29	3.0	1.0	2.7	3.7	3.0	8.3	11.3	1.0	2.0	3.0	1.0	1.0	2.0	4.7	12.0	16.7
May 31	3.0	5.7	8.8	14.5	3.7	18.3	22.0	0	2.7	2.7	1.8	8.2	10.0	22.3	73.3	95.7
June 3	2.5	1.8	15.8	17.7	0.5	27.0	27.5	0	2.8	2.8	1.2	22.8	24.0	7.0	142.7	149.7
June 4	3.3	2.9	6.1	9.0	3.1	10.1	13.3	0.3	1.5	1.8	0.3	0.8	1.0	19.0	41.5	60.5
June 7	14.0	10.2	11.9	22.1	7.5	11.0	18.5	1.3	2.7	4.0	1.4	5.6	7.0	31.1	52.6	83.7
June 10	3.0	12.0	33.7	45.7	15.0	26.0	41.0	1.7	5.3	7.0	1.7	8.3	10.0	41.0	95.0	136.0
June 12	3.0	5.0	6.0	11.0	10.8	10.8	21.5	2.7	0.7	3.4	2.7	8.0	10.7	27.7	29.0	56.7
June 13	8.0	2.8	8.3	11.1	1.9	12.3	14.1	0.5	2.0	2.5	1.3	4.4	5.7	6.9	27.9	34.8
June 14	8.0	12.5	17.4	29.9	14.8	22.6	37.4	0.4	3.3	3.7	8.6	19.3	27.9	37.4	64.4	101.8
June 17	2.0	12.5	3.5	16.0	11.0	8.0	19.0	3.5	0	3.5	14.5	8.0	22.5	85.0	42.0	127.0
June 18	7.0	3.0	5.4	8.4	1.9	9.4	11.3	0.5	1.5	2.0	5.6	9.6	15.3	9.3	22.1	31.4
June 19	2.0	0	3.5	3.5	2.5	15.5	18.0	0	1.0	1.0	8.0	15.5	23.5	23.0	74.0	97.0
June 20	10.0	9.6	18.3	27.9	3.4	18.6	22.0	0.1	2.7	2.8	16.2	23.1	39.3	38.7	74.1	112.8
June 24	8.0	3.9	9.4	13.3	3.4	12.1	15.5	0.1	1.6	1.7	3.3	6.1	9.4	10.9	29.1	40.0
June 25	9.0	10.2	18.2	28.4	11.2	20.9	32.1	0.3	3.6	3.9	12.4	20.1	32.6	35.7	63.6	99.2
June 27	6.0	18.7	18.2	36.8	19.2	23.3	42.5	1.5	1.2	2.7	3.0	4.0	7.0	85.0	93.0	178.0
July 1	7.0	21.4	33.9	55.3	15.8	21.5	37.3	0.6	2.6	3.2	36.3	44.4	80.7	125.2	166.2	291.3
July 3	9.0	7.2	13.4	20.7	7.9	16.4	24.3	0.2	2.3	2.5	11.3	16.0	27.3	25.2	44.7	69.9
July 8	11.0	14.5	24.4	38.9	16.8	25.8	42.6	0.8	5.5	6.3	41.4	47.1	88.5	78.4	106.6	185.0
July 11	7.0	9.6	27.4	37.0	12.6	32.9	45.4	0.6	2.6	3.2	9.6	35.2	44.8	31.3	90.4	121.7
July 15	10.0	14.4	36.9	51.3	11.9	33.6	45.5	0.1	2.9	3.0	32.9	57.5	90.4	69.2	151.1	220.3
July 16	10.0	25.6	23.8	49.4	23.7	24.4	48.1	1.9	3.1	5.0	45.5	50.0	95.5	97.5	103.5	201.0
July 22	10.3	39.6	25.5	65.2	27.3	24.3	51.5	1.6	0.8	2.4	23.5	31.5	55.1	92.9	83.6	176.5
July 25	10.8	22.1	20.4	42.5	30.7	28.8	59.5	2.1	2.6	4.7	14.4	31.0	45.4	66.0	76.5	142.5
July 30	9.0	16.6	17.6	34.1	27.0	26.8	53.8	1.6	1.2	2.8	15.5	21.4	36.9	55.1	60.3	115.4
August 1	10.0	33.9	34.9	68.8	57.6	57.9	115.5	1.0	1.4	2.4	45.7	43.7	89.4	129.0	125.5	254.5
Overall	185.9	14.1	19.1	33.2	15.0	22.4	37.4	0.9	2.4	3.3	17.0	24.7	41.7	48.2	74.8	123.0

[a]All ciconiiforms combined, including Great Egret, Cattle Egret, Snowy Egret, Black-crowned Night-Heron, Great Blue Heron (*Ardea herodias*), White-faced Ibis (*Plegadis chihi*), Glossy Ibis (*Plegadis falcinellus*), and unidentified ciconiiforms.

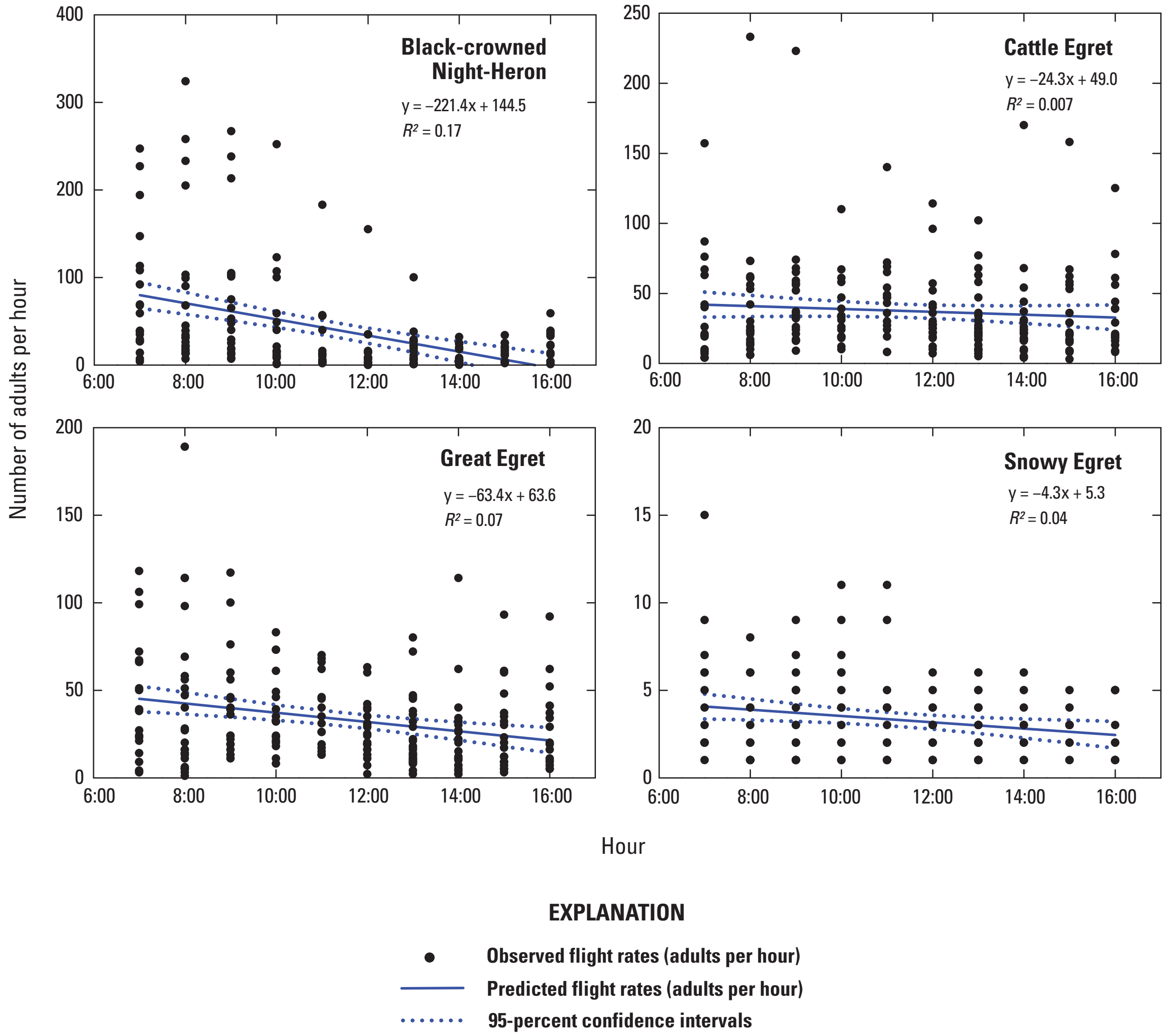

Figure 11. Number of flights per hour for ten 1-hour time periods for Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and Snowy Egret (*Egretta thula*) at Chase Lake National Wildlife Refuge, North Dakota, 2013.

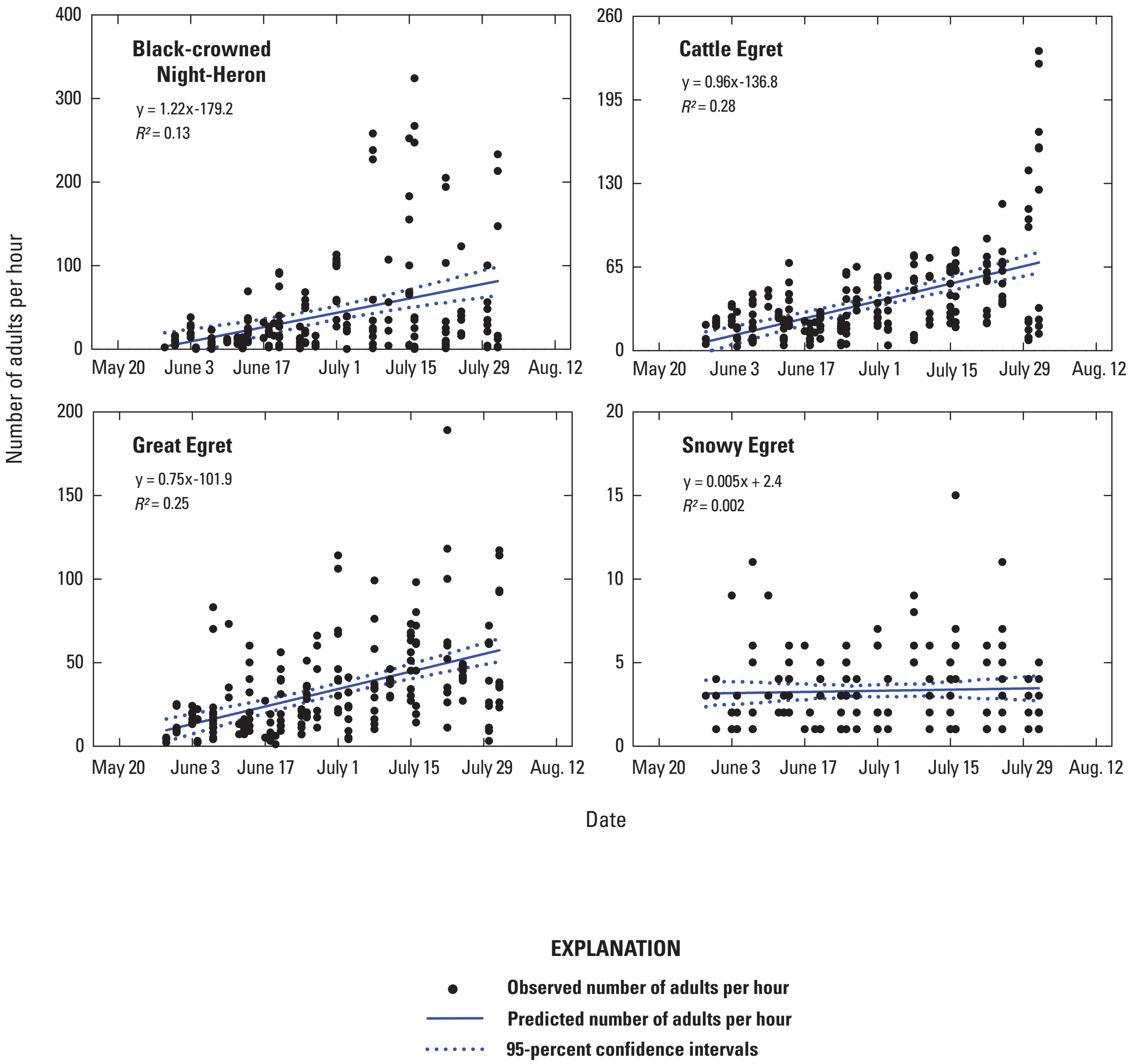

Figure 12. Number of flights per hour for 26 survey dates for Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and Snowy Egret (*Egretta thula*) at Chase Lake National Wildlife Refuge, North Dakota, 2013.

Table 6. Comparison of the total number of nests, total number of flights, and average flight rates for Great Egret (*Ardea alba*), Cattle Egret (*Bubulcus ibis*), Snowy Egret (*Egretta thula*), Black-crowned Night-Heron (*Nycticorax nycticorax*), and all ciconiiform species combined at Chase Lake National Wildlife Refuge, North Dakota, 2013.

Label	Great Egret	Cattle Egret	Snowy Egret	Black-crowned Night-Heron	All ciconiiforms combined[a]
Total nests[b]	419 (0.234)	557 (0.317)	18 (0.010)	562 (0.319)	1,759
Total flights[c]	6,604 (0.290)	7,514 (0.330)	480 (0.021)	7,398 (0.325)	22,737
Average flight rate[d]	33.2 (0.254)	37.4 (0.286)	3.3 (0.025)	41.6 (0.319)	132.9
Average flight rate[e] (morning)	41.4 (0.231)	41.9 (0.234)	3.9 (0.022)	62.6 (0.350)	179.0
Average flight rate[f] (afternoon)	26.2 (0.302)	33.9 (0.391)	2.8 (0.032)	15.8 (0.182)	86.8
Average flight rate[g] (early season)	17.0 (0.200)	21.3 (0.251)	3.1 (0.036)	15.3 (0.180)	84.9
Average flight rate[h] (late season)	41.7 (0.259)	47.2 (0.293)	3.4 (0.021)	54.1 (0.336)	161.2

[a]All ciconiiforms combined, including Great Egret, Cattle Egret, Snowy Egret, Black-crowned Night-Heron, Great Blue Heron (*Ardea herodias*), White-faced Ibis (*Plegadis chihi*), Glossy Ibis (*Plegadis falcinellus*), and unidentified ciconiiforms.

[b]Total number of ciconiiform nests from within-colony counts.

[c]Total number of flights (inbound and outbound combined) of ciconiiforms for ten 1-hour time periods and 26 dates.

[d]Number of flights per hour, averaged across ten 1-hour time periods (7:00–17:00 central daylight time).

[e]Number of flights per hour, averaged across five 1-hour morning time periods (7:00–12:00 central daylight time).

[f]Number of flights per hour, averaged across five 1-hour afternoon time periods (12:00–17:00 central daylight time).

[g]Number of flights per hour, averaged across 13 dates, early in the breeding season (May 29–June 20, 2013).

[h]Number of flights per hour, averaged across 13 dates, late in the breeding season (June 24–August 1, 2013).

The perimeter nest counts represented 18.8 percent of the 1,928 active ciconiiform nests counted in 11 subcolonies in 2012. This was well below the target of 50 percent (and the preferred target of 75 percent) recommended by Steinkamp and others (2003), although the authors provided no basis or justification for this target. Nonetheless, we found a positive relationship between the number of nests counted during perimeter counts and the number of nests counted during within-colony counts for the three most common ciconiiform species and all ciconiiform species combined. Perimeter counts at Chase Lake, however, were hampered by disturbance to nesting birds from observers. The median quality of the perimeter counts was assessed by observers as poor. At some observation points, observers terminated an individual perimeter count early if the disturbance level was deemed excessive. Many ciconiiforms and other waterbirds flushed from their nests when an observer approached within 50 m of the perimeter of the subcolony; flushing ciconiiform adults away from their nests compromises perimeter nest counts because an adult must be present at the nest to identify the species. Our efforts to camouflage observers using blinds or different attire on observers did not alleviate the disturbance on nesting herons, egrets, pelicans, and gulls. The dense canopy for some shrub subcolonies also precluded a thorough perimeter count. Dodd and Murphy (1995) found perimeter counts to be imprecise because observers found it difficult to view more than a small part of a large colony from a single vantage point. Additionally, the presence of thousands of ground-nesting waterbirds at the South Island presented a challenge for observers conducting perimeter counts. For example, in 2012, about 16,245 pelican nests were present on the South Island, including 3,089 nests that were directly below the shrub subcolonies. Perimeter counts were conducted at only 11 of the 26 shrub subcolonies before we discontinued the surveys in mid-June; observation points at some of the larger subcolonies were not completed. The positive relationships between perimeter counts and within-colony nest counts indicate that, under certain circumstances, perimeter counts could be used in a predictive model to estimate total nest abundance. The inconsistent application of the survey methods in this study, however, could have provided inaccurate results for the perimeter counts. The extent of this issue is unknown, and any predictive models from these counts could be misleading and are not recommended.

Flightline surveys at Chase Lake documented patterns of ciconiiform activity that were unknown for this region, but generally followed patterns reported in the literature. Ciconiiform flights to and from the South Island at Chase

Lake were greatest in the morning and least in the afternoon for the common ciconiiform species, which likely reflected nest exchanges between incubating or nest-guarding adults in the morning (Erwin and Ogden, 1980; Erwin, 1981; Cox and others, 2017). Large-scale departures in the morning also have been documented at other mixed-species colonies during flightline surveys (Erwin and Ogden, 1980; Erwin, 1981, 1983; Maccarone and Parsons, 1988), although many of these studies were in coastal areas, where ciconiiform activity is affected by wind-driven and lunar tides. Erwin and Ogden (1980) similarly showed that time of day, nesting phase, and species influenced the relationship between flight rates and number of active nests in colonies in coastal areas. Maccarone and Parsons (1988) reported that Snowy Egret and Great Egret flight frequencies did not differ among four 3-hour time periods; however, Cattle Egrets were recorded less often in the early morning and more often in the late afternoon. Erwin and Ogden (1980), however, reported higher flight rates in the morning than in the afternoon for Cattle Egrets and Snowy Egrets.

At Chase Lake, Cattle Egrets did not show a relationship between time of day and the number of flights to and from the South Island. Our approach with the flightline surveys was predicated on the assumption that birds will forage away from the South Island. Great Egrets, Snowy Egrets, and Black-crowned Night-Herons typically forage in wetlands near Chase Lake, but the Cattle Egret typically forages in terrestrial habitats (Belzer and Lombardi, 1989; Telfair, 2019), including on the South Island (L. Igl, personal observation). The Cattle Egret is described as an opportunistic feeder that forages primarily on insects, frogs and toads, and other small animals, and often is associated with grazing livestock (fig. 13; Jenni, 1973). Thus, Cattle Egrets may not necessarily have to leave the island to locate food for their young or may not leave in a predictable direction. Maccarone and Parsons (1988), however, reported higher flight frequencies for Cattle Egrets later in the day and lowest frequencies in the early morning.

Ciconiiform flights at Chase Lake also were greatest later in the nesting season. As dependent chicks grow, adults reduce

Figure 13. Adult Cattle Egret (*Bubulcus ibis*) associated with grazing cattle in a grassland near Chase Lake National Wildlife Refuge, North Dakota. Photograph by Lawrence D. Igl, U.S. Geological Survey.

their brooding activity, and both adults from a nest respond to the chick's demands for more food by increasing the number of daily foraging flights later in the season (Pratt, 1970; Siegfried, 1972; Bryan and others, 1995; Coulter and others, 1999; Maccarone and others, 2010, 2012). Erwin and Ogden (1980) showed that the phase of the nesting cycle had the greatest effect on flight traffic of adults for four ciconiiform species in multiple colonies in the eastern United States.

Flightline surveys are an index to abundance but lack comparability to within-colony nest counts because the two methods provide measures of different things (that is, adult activity away from the colony as compared to the number of nests within the colony), even if each method provides the most accurate measure of the thing that is measured. The overall proportions of flights generally reflected the proportions of the within-colony nest counts for the four most common species. Flightline surveys have been recommended by some authors (Cobb, 1994; Paul and Paul, 2004; Sprandel, 2009) but not others (Kushlan, 2011). Sprandel (2009) and Kushlan (2011) argued that a major disadvantage of the flightline approach is the lack of comparability with within-colony nest counts or other methods. Sprandel (2009) recommended this method for management agencies that have limited staff or that use volunteers, because within-colony counts may not be feasible because of accessibility, canopy closure, and desire to avoid disturbances. Kushlan (2011) argued that there are few applications where this method is justified, except in situations in which logistic constraints allow no other choice. Some authors have suggested that flightline surveys early in the breeding season are assumed to equal the number of breeding pairs, based on the assumption that one adult per pair would be attending the nest (Erwin, 1981; Jones, 2008). This assumption has rarely been verified, and breeding activity and exchange rates between mates likely vary among waterbird species, colonies, and regions. Erwin and Ogden (1980) reported that flightline counts tended to underestimate nest counts at large wading bird colonies, whereas Cox and others (2017) reported that flightline surveys overestimated Reddish Egret (*Egretta rufescens*) abundance compared with within-colony nest counts.

In addition to variation related to the time of day and season, our results indicated variation in detection of inbound and outbound ciconiiforms. The average number of outbound flights was 30.8 percent higher than the average number of inbound flights. The potential source for this difference in detection may be related to the behaviors of adult ciconiforms. Our approach assumed that all outbound and inbound flights were on the southside of Chase Lake, but this assumption may be unrealistic, and some birds might have returned in a direction that was different than the direction from which they departed. These ciconiiform species are opportunistic foragers, and their foraging locations in the surrounding landscape may be especially variable after they depart the colony. Also, some birds may not have returned to the colony until after our surveys (17:00 CDT). Black-crowned Night-Herons, for example, have nocturnal and crepuscular feeding habits, and often forage between the evening and the early morning or feed both day and night during the breeding season (Hothem and others, 2010). More study is warranted on the foraging locations and behaviors of ciconiiform species at Chase Lake.

Another inherent challenge with flightline surveys at Chase Lake is that this waterbird colony includes more than just heron and egrets, such that flightline observers were overwhelmed by thousands of other birds departing and entering the waterbird colony, including pelicans, cormorants, and two species of gulls. For example, an estimated 15,953 pelican nests (31,906 adults) were counted on the South Island in 2013 (table 1.1). We attempted to count cormorant flights along with ciconiiforms in 2013 but abandoned this effort because the observers found it difficult to count the large number of cormorants exiting and entering the colony along with the herons, egrets, gulls, and pelicans. Kushlan (2011) indicated that, at large colonies, flights are usually large and rapid, and counts can be difficult, leading to errors in numbers and identification.

Since the ciconiiforms started nesting on the South Island in the mid-1990s, the tall shrubs in the subcolonies at Chase Lake have been dying (fig. 14) (A. Bartos, personal observation), and these changes in the size and quality of the tall-shrub subcolonies over time could change the relationships observed between perimeter nest counts and within-colony nest counts. Some shrubs near the water's edge have succumbed to rising water levels (fig. 15). By 2017, 6 of the subcolonies were submerged or inundated, 14 subcolonies were partially inundated, and only 6 subcolonies remained in the upland portion of the island. The shrubs also have been damaged by American beavers (*Castor canadensis*) (fig. 16), and other shrubs may be dying from nesting activities of the waterbirds themselves. Defoliation; the covering of leaves by droppings; the removal of twigs for nest construction; and the potentially harmful increases in soil nitrates, nitrites, and phosphates associated with the birds' guano (guanotrophication) also may be killing the native shrubs in these subcolonies (R.C. Telfair, written commun. [n.d.]; Telfair, 1983; Grant and Watson, 1995; Telfair and others, 2000; Telfair and Bister, 2004). Chokecherry and hawthorn do not appear to be guano-tolerant, and the life span of the heron and egret subcolonies at Chase Lake may be shortened by guanotrophication from the large concentrations of colonial waterbirds nesting within and under these tall shrubs on this island. The ciconiiforms at Chase Lake continued to nest in the skeletons of the dead and dying shrubs, but regrowth of these shrubs is not evident (L. Igl and A. Bartos, personal observations). In northeastern South Dakota, Naugle and others (1996) studied a mixed-species ciconiiform nesting colony in flooded trees that were inundated during this same prolonged wet period in this region; that nesting colony is no longer active (D. Azure, written commun. [n.d.]). Other authors also have noted the ephemeral nature of some waterbird colonies (Bancroft and others, 1988; Burger, 1989; Brunton, 1997; Ward and others, 2011).

In summary, we acknowledge the challenges in selecting survey methods for ciconiiform species in a large mixed-species waterbird colony. Given these challenges, Cox and

Figure 14. Dead shrubs on the South Island at Chase Lake National Wildlife Refuge, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

others (2017) argued that careful consideration of appropriate survey methods is warranted. The most appropriate combination of survey approaches for ciconiiforms at Chase Lake will depend on the need for annual estimates of nest abundance of ciconiiform species, balanced with the financial, personnel, and logistical constraints associated with the survey methods. Given the potential for disturbances of nesting waterbirds, perimeter counts are not recommended at Chase Lake. Flightline surveys in 2013 provided baseline information for adult activity to and from the nesting colony, but additional years of data collection are needed to make recommendations related to optimal dates or times of day to conduct flightline surveys. Our results indicate that managers may use within-colony nest counts to survey ciconiiform nests when feasible and when disturbances can be minimized. Managers should consider several factors when determining if within-colony nest counts are feasible, including the experience of the observers, the nesting stage (to avoid destruction of eggs or premature fledging), adult flushing and defensive behaviors, and weather extremes (A. Bartos, personal observation). We emphasize the importance of using highly trained and skilled observers, who can make informed decisions concerning the timing of within-colony nest counts and when to terminate them to limit disturbances. If the areas of the shrub subcolonies are known in the future (for example, through aerial or satellite imagery), the equations from the negative binomial regression models from this study can be used to predict the number of nests for Black-crowned Night-Heron, Great Egret, Cattle Egret, and all ciconiiforms combined. Less disruptive technologies, such as unmanned aerial vehicles, are advancing rapidly and becoming part of monitoring applications for colonial waterbirds (Bakó and others, 2014; Afán and others, 2018; Barr and others, 2018); these technologies in combination with thermal imagery may provide a feasible mechanism to monitor ciconiiforms at Chase Lake to determine changes in nest abundance.

Figure 15. Dead shrubs in standing water on the edge of the South Island at Chase Lake National Wildlife Refuge, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

Figure 16. Shrub damage by American beaver (*Castor canadensis*) on the South Island at Chase Lake National Wildlife Refuge, North Dakota. Photograph by Alisa J. Bartos, U.S. Fish and Wildlife Service.

Part B. Image Analysis of Nesting American White Pelicans

The abundance of American White Pelicans nesting at Chase Lake National Wildlife Refuge is among the highest in North America, averaging over 16,000 nests between 2012 and 2017 (table 1.1). At its current abundance and area, within-colony surveys of pelican nests are impractical. Moreover, within-colony surveys can be inaccurate in large colonies, particularly in complex landscapes with high relief or where parts of the colony can be assessed only from a poor vantage point (Fraser and others, 1999; Trathan, 2004).

Historically, three census methods have been used to estimate the abundance of American White Pelicans at Chase Lake: visual counts of nests or adults within the nesting colony (1905–71), manual counts of nests from aerial photographs (1972–2002), and semiautomated counts of nests from aerial photographs using remote-sensing software (2003–17) (fig. 2, table 1.1). The current species diversity and abundance of waterbirds at Chase Lake has made it increasingly difficult to reliably count pelican nests or adults within the colony without disturbing nesting birds. Nest counts from aerial photographs have been recommended as a standardized and less disruptive census method for waterbird colonies (Nettleship, 1976; Birkhead and Nettleship, 1980; Sidle and Ferguson, 1982; Dolbeer and others, 1997; Steinkamp and others, 2003). Sidle and Ferguson (1982) assessed the use of aerial images to estimate the number of pelican nests at Chase Lake and determined that individual nesting pelicans were discernable, could be distinguished from loafing and nonbreeding birds and from other ground-nesting waterbirds (for example, gulls and cormorants), and could be manually counted.

Recent advances in remote-sensing technology and digital-analyses software have allowed for semiautomated counting of ground-nesting colonial waterbirds from aerial photographs that are more efficient than traditional manual counts from aerial photographs (Laliberte and Ripple, 2003; Trathan, 2004; Barber-Meyer and others, 2007; Descamps and others, 2011; Bakó and others, 2014; Afán and others, 2018). Since 2003, the U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, has been using remote-sensing software to count pelican nests at Chase Lake. The annual surveys of nesting American White Pelicans in recent years have proven critical in documenting changes in abundance at Chase Lake and other regional pelican colonies (Sovada and others, 2005, 2008). Since 2002, weather events and the West Nile virus have been implicated in major nest failures and high mortality events of pelican chicks at the Chase Lake colony (Sovada and others, 2008, 2013, 2014).

With improved high-resolution color photography and remote-sensing techniques, user-assisted, semiautomated counting methods based on image-analysis methods are becoming a practical alternative to traditional manual counts (Chabot and Francis, 2016). Digital-image processing techniques are becoming increasingly reliable and accepted as a sampling tool for congregations of birds (Gilmer and others, 1988; Strong and others, 1991; Laliberte and Ripple, 2003; Trathan, 2004; Barber-Meyer and others, 2007; Groom and others, 2013). For example, at a large American White Pelican colony in Minnesota, DiMatteo and others (2015) reported that manual counts of pelican nests were significantly correlated to counts from an automated count routine using UTHSCSA ImageTool (Laliberte and Ripple, 2003). Descamps and others (2011) developed an open-source freeware program that automatically extracts and counts the number of birds in aerial images of dense aggregations. Milton and others (2006) used commercially available eCognition (Trimble Navigation, Sunnyvale, Calif.) for digital-image analyses of molting flocks of Common Eider (*Somateria mollissima*). Barber-Meyer and others (2007) used remote-sensing technology to estimate the relative abundance of Emperor Penguins (*Aptenodytes forsteri*) at inaccessible colonies.

Semiautomated digital-image processing techniques have been used to estimate nest numbers of American White Pelicans at Chase Lake for over a decade. During early development of this method in 2003, Sovada and others (unpub. data) compared traditional manual counts from aerial photographs with counts from digital-image processing and concluded that digital-image processing provided estimates of nest abundance with an acceptable level of precision (within 3–5 percent) for a small area. The objective of this study was to further assess semiautomated image analysis to estimate abundance of American White Pelicans as an alternative to manually counting nests from aerial imagery (Sidle and Ferguson, 1982). We focused this portion of the study on the North Island between 2001 and 2013, because ground nests of pelicans on the North Island were not obstructed by the cover of tall shrubs and because the North Island provided a wide range of nest abundances across years to facilitate comparisons between manual counts and counts from semiautomated image analysis. We note, however, that semiautomated image analysis of pelican nests has been used to estimate nests throughout the Chase Lake colony since 2003. Nest estimates for the entire pelican colony between 1905 and 2017 are included in table 1.1 and figure 2, with adjustments (that is, within-colony counts) in recent years for pelicans nesting beneath the tall shrubs on the South Island.

Methods

Since 1980, aerial photographs of the nesting islands and peninsulas at Chase Lake have been taken by U.S. Fish and Wildlife Service personnel to estimate the number of viewable or photographable adult American White Pelicans and other ground-nesting colonial waterbirds on their nests (Sidle and Ferguson, 1982). Photographs typically were taken from a small, fixed-wing aircraft (for example, Cessna 180; Sidle and Ferguson, 1982) during peak incubation of pelican nests, typically between mid-May and early June, when most of the asynchronous subcolonies of nesting pelicans had formed but before the young from the earliest nesting pelicans had formed crèches of juveniles.

The timing of the annual aerial photography generally coincided with local colony attendance patterns and nest-site faithfulness of incubating and brooding adult pelicans. Aerial photographs usually were taken between 9:00 and 11:00 CDT, with the assumption that one adult per pair would be attending the nest during this period while its mate was foraging away from the nesting colony (Lingle, 1977; Sidle and Ferguson, 1982; DiMatteo and others, 2015; A. Bartos and R. Woodward, personal observation). Thus, each bird in the nesting colony represented a single nest site. The timing of this aerial photography also provided images with fewer shadows that might influence image analysis using digital-analysis software (R. Woodward, personal observation).

In most years, photographers attempted nearly vertical photographs from the belly of the aircraft. Between 1980 and 2007, 35-millimeter film or slide-film formats were the primary medium used in aerial photography at Chase Lake; the film was developed by a commercial film processor. Hardcopy photographs were scanned with a desktop scanner to produce digital images for nest counts. Since 2007, aerial photographs of the nesting islands and peninsulas were taken with digital single-lens reflex cameras. In all years, several passes over the nesting islands or peninsulas were necessary to obtain overlapping photographs of the entire nesting colony (Sidle and Ferguson, 1982). Overview photographs of each nesting island or peninsula also were taken to facilitate piecing together or lining up overlapping photographs from individual passes and to reduce duplication of counts. As with Sidle and Ferguson (1982), no disturbances or movements of incubating pelicans, cormorants, gulls, or ciconiiforms were noted during the flights or on the aerial photographs.

Manual nest counts of pelicans were completed from enlarged printed copies of photographs or digital images taken of the North Island during the breeding season of 2001 through 2013. Nest counters also manually counted nests of Double-crested Cormorants and gulls. Species were identified to the lowest achievable taxonomic level; gull species (that is, Ring-billed Gulls and California Gulls) could not be distinguished on aerial photographs and thus were classified as “gulls.” Nest counters selected the clearest images with the highest resolution for counting. Overview photographs were used to align individual close-up photographs to ensure complete coverage of the colony without duplicating counts (Steinkamp and others, 2003). Nest counters drew boundaries around count areas or subcolonies to designate areas that had not been counted in other photographs. To avoid duplicating counts during manual counts, each bird on a nest was marked by placing a dot on the individual with a felt-tipped marker; different colored markers were used for different species. Loafing birds, nonbreeding birds, or adults relieving their mates were distinguished from adults on nests based on nest signs, incubation posture, and spacing behavior of attending adults (Sidle and Ferguson, 1982; R. Woodward and A. Bartos, personal observations).

We also estimated counts of nesting pelicans on the North Island between 2003 and 2013 by applying a pixel-based, user-assisted method for digital counting of nests using two commercially available remote-sensing software packages (TNTMips 9.2 [MicroImages, Inc., Lincoln, Nebraska] and ArcMap 10.1 [Esri, Inc., Redlands, Calif.]). The white color of American White Pelicans typically contrasts with the island background. On digital imagery, pelicans typically register as several pixels; pelican color is typically heterogeneous with brighter white pixels in the center and slightly darker pixels near the boundary. The number of pixels per pelican was more than 100 in higher-resolution photographs but appreciably lower in lower-resolution photographs (R. Woodward, personal observation). In most years, the photographs of the North Island lacked sufficient contrast, quality, or resolution to count gulls and cormorants using TNTMips or ArcMap software packages; gulls often registered as a low number of pixels, and nesting cormorants blended with the ground substrate or shadows.

The steps involved in counting nesting pelicans using remote-sensing software varied with the two software packages, but generally included importing the image, defining a region-of-interest, completing object analysis and supervised classification, converting pelican rasters to vectors, and exporting the results to a spreadsheet. Given that photographs from different years varied in resolution and contrast, some processing or enhancement steps using functions in ArcMap and TNTMips were necessary for some images to improve contrast (that is, adjusting the difference between the lightest and darkest colors) and brightness between the bird and the background substrate; the thresholds used to filter and separate pixels of nesting birds from background pixels varied among images. The digital-image analysis of aerial photographs began by defining a region of interest for each pelican subcolony by drawing a polygon around a counting area (for example, a subcolony) to mask out peripheral areas (for example, areas with no nests or areas where nests are concealed by tall, dense shrubs). This masking approach reduced subsequent processing time because the region of interest was much smaller than the original digital image (fig. 17). Masking also allowed an experienced nest counter to exclude loafing or flying birds, nonbreeding birds, or adults relieving their mates from the region of interest. Next, we performed supervised classification based on the spectral properties of the image. Nesting birds were identified within the region of interest by compiling pixel values for individual birds. For example, adult pelicans are expressed as relatively bright image objects, forming rectangular or oval clusters of pixels, and gulls are expressed as smaller, less bright image clusters of fewer pixels (fig. 17). The supervised classification resulted in a set of discrete pixel areas that represented individual “pelicans” on nests. The “raster pelicans” were then converted into “vector pelicans” with geometric boundaries. There was spectral overlap between pelicans and other white birds in the aerial images. For each image, we determined the minimum and maximum sizes (that is, areas) that consistently represented

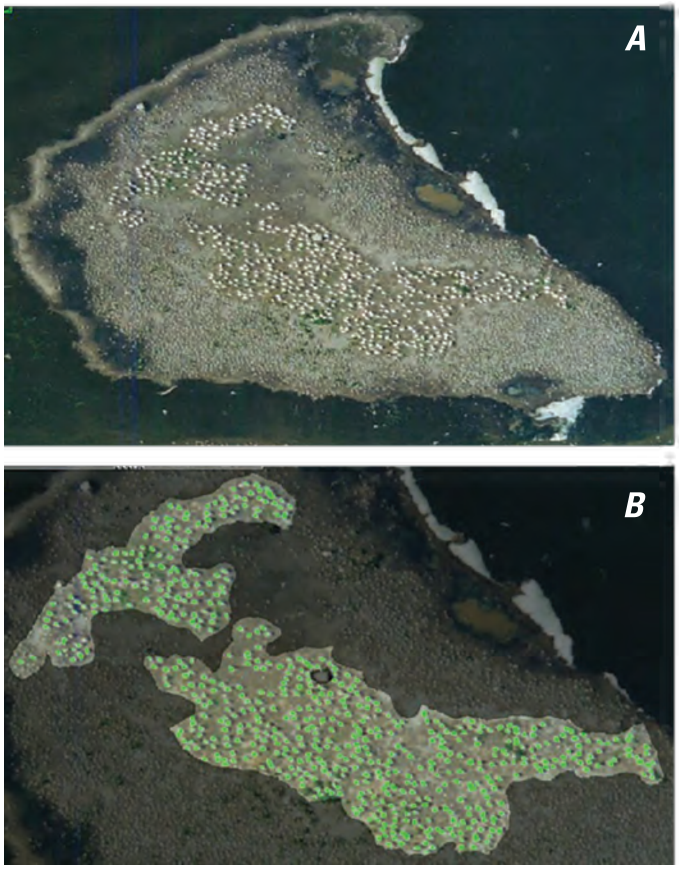

Figure 17. Digital-image data that were interpreted as representing individual American White Pelicans (*Pelecanus erythrorhynchos*) on nests. *A*, Digital aerial image of adult pelicans (center) and gulls (perimeter) attending nests. *B*, 623 individual pelicans were identified and counted with semiautomated digital-image analysis.

one pelican by examining the polygon statistics in combination with the original aerial image; any polygon area below the minimum value was not a pelican, and any value above the maximum value represented two or more pelicans. Finally, we used an automated counting routine to count these discrete pelicans (that is, individual nesting birds).

We used regression analysis (PROC REG; SAS Institute, Inc., 2017) to assess the relationship between abundance estimates from manual counts of pelican nests and abundance estimates from TNTMips and ArcMap counts on the North Island at Chase Lake, 2001–13. We were interested in predicting the number of actual pelican nests on the island based on the semiautomatic counts using TNTMips and ArcMap. We considered this problem to be a classic calibration (inverse-prediction) problem (Neter and others, 1990). We assumed that the manual-based counts from imagery were the "truth" (that is, the *x* variable) and the semiautomated imagery counts using remote-sensing software were the "measured" variable (that is, the *y* variable). We first fit a simple linear regression model with *y* as a function of *x*:

$$y = \beta_0 + \beta_1 x \,, \tag{1}$$

where

β_0 is the y -intercept, and

β_1 is the slope of the regression line.

Through algebraic manipulation, we derived an inverse regression model that predicted the "true" counts from the semiautomated counts, including appropriate parameters for quantifying the standard error of the predicted *x*-value and accompanying confidence intervals for the new values. The inverse regression model was calculated as

$$\hat{x}_{new} = \frac{y_{new} - \beta_0}{\beta_1} \,, \tag{2}$$

where

$\hat{x}_{new}$ is the predicted "true" count, and

y_{new} is the estimated count from the semiautomated count.

The confidence intervals were computed as

$$\hat{x}_{new} \pm \left(t_{\alpha/2,\, n-2}\right)\sqrt{s^2\left\{\hat{x}_{new}\right\}} \,, \tag{3}$$

where

n is the number of observations,

$t_{\alpha/2, n-2}$ is the *t*-statistic with α/2 significance level, and

$n-2$ is degrees of freedom.

The variance (s^2) of $\hat{x}_{new}$ was calculated as

$$s^2\left\{\hat{x}_{new}\right\} = \left(\frac{MSE}{\beta_1^2}\right)\left[1 + \frac{1}{n} + \frac{\left(\hat{x}_{new} - \overline{x}\right)^2}{\sum\left(x_i - \overline{x}\right)^2}\right], \tag{4}$$

where

MSE is mean square error from the original regression model,

$\overline{x}$ is the mean of the manual count, and

$\sum\left(x_i - \overline{x}\right)^2$ is the corrected sum-of-squares.

To further assess this calibration effort, we computed and summarized the mean absolute difference and the mean difference in number of nests between the original *x*-value in our dataset and the new predicted *x*-value from the inverse regression. The full datasets used for the analyses in this objective are included in tables within this report.

Results

Based on traditional manual counts from aerial photographs on the North Island on Chase Lake between 2001 and 2013, annual abundance estimates of the three focal ground-nesting species or groups varied from 0 to 3,894 American White Pelican nests, 1,237 to 6,045 gull nests, and 0 to 1,236 Double-crested Cormorant nests (table 7). Using semiautomated image processing, TNTMips and ArcMap counted

Table 7. Estimates of the number of nests of American White Pelicans (*Pelecanus erythrorhynchos*), gulls (*Larus* spp.), and Double-crested Cormorants (*Phalacrocorax auritus*) from aerial photographs taken of the North Island at Chase Lake National Wildlife Refuge based on traditional manual counts and counts from digital-image analysis using TNTMips and ArcMap geographical information systems, 2001–13.

[--, no data]

Year	American White Pelican			Gulls	Double-crested Cormorant
	Manual	TNTMips[a]	ArcMap	Manual[b]	Manual[b]
2001	2,258	2,187	2,104	3,331	449
2002	3,894	3,939	3,111	4,041	1,236
2003	1,728	1,727	1,847	6,045	347
2004	1,555	--	1,240	1,862	15
2005	1,915	1,765	1,802	5,083	146
2006	3,101	3,202	3,233	4,382	845
2007	1,077	1,157	1,110	4,594	536
2008	2,579	2,716	2,710	4,287	386
2009	2,180	2,135	2,150	4,661	118
2010	1,174	1,142	1,181	5,336	740
2011	482	450	431	1,237	307
2012	0	0	0	3,626	260
2013	40	50	40	3,308	0
Total	21,983	20,463	20,959	51,793	5,385

[a]Nest count estimates from TNTMips were not completed in 2004.

[b]In most years, the photographs of the North Island were not of sufficient quality or resolution to count gulls and cormorants using TNTMips or ArcMap geographical information systems; estimates of nests for these species were completed using traditional manual counts from aerial photographs. During perimeter counts from a boat in 2012, A. Bartos estimated that, on average, 12.7 and 87.3 percent of the nests were California Gulls and Ring-billed Gulls, respectively. Lingle (1977) reported similar proportions in 1976 (18.9 percent for California Gulls compared to 81.1 percent for Ring-billed Gulls) and 1977 (12.6 for California Gulls compared to 87.4 percent for Ring-billed Gulls). Sidle and Ferguson (1982) estimated that 24.7 percent of the nests in 1980 were California Gulls and 75.3 percent were Ring-billed Gulls.

0 to 3,939 pelican nests and 0 to 3,233 pelican nests, respectively. The mean absolute differences between the estimated TNTMips and ArcMap counts and the traditional manual counts were 5.4 and 6.5 percent, respectively.

In the regression analyses, 99.6 and 95.7 percent of the variation in the semiautomated nest counts from TNTMips and ArcMap, respectively, was explained by the models (figs. 18 and 19; table 8). Both estimates from the semiautomated counts had low mean absolute differences between the original x-value and the predicted x-value (56.5 nests for TNTMips and 172.8 nests for ArcMap; table 8). TNTMips underpredicted nest counts by an average of 0.008 nest between the original manual count value and the predicted new manual count value, and ArcMap overpredicted by an average of 0.008 nest between the original manual count value and the predicted new manual count value.

The time spent on image preparation and nest counts differed between semiautomated image processing and manual methods, but the overall time spent on counting and processing was similar (manual preparation average=182 minutes, manual count average=23.8 minutes, manual total average=206.8 minutes; semiautomated preparation average=13.1 minutes, semiautomated count average=201.2 minutes, semiautomated total average=214.3 minutes). We only had image preparation and counting time for the semiautomated counting in ArcMap; we suspect that image preparation and counting time would be similar for TNTMips.

Discussion

Our results indicate that digital-image processing using remote-sensing software provides a reasonably accurate estimate of the number of pelican nests in open habitat. Estimates of the number of pelican nests from digital-image processing using two commercially available geographical information systems were comparable to those of traditional manual counts from aerial photographs. Both remote-sensing systems provided excellent fits based on results from the regression and inverse regression models. On average, TNTmips slightly underpredicted the manual counts, and ArcMap slightly overpredicted the manual counts. However, regardless of the technique, both counting methods required knowledge and assistance from experienced counters in differentiating nesting birds from nonnesting birds.

The manual and the semiautomated nest counts may have been successful, in part, because we focused our attention on the pelicans nesting on the shrubless North Island; that is, the lack of shrubs on the North Island may have enabled fairly precise estimates of the number of pelican nests. Based on our experience with the semiautomated counts using TNTMips, however, it is worth noting that this method also produced fairly precise estimates when we included other nesting islands and peninsulas in the analyses, including the South Island, which supports many small and large clumps of tall shrubs. For example, we reassessed our regression analysis (PROC REG; SAS Institute, Inc., 2017) between manual counts and TNTMips counts of pelican nests on the North Island (2001–13) by including additional counts from the Middle Island (2003 and 2005), South Island (2003 and 2005), and all islands and peninsulas combined (1992, 1998, and 2015) at Chase Lake (table 1.2, fig. 1.1). In this expanded analysis, manual counts explained 99.8 percent of the variability in nest counts from semiautomated counts using TNTMips. Admittedly, estimates of pelican nest abundance using aerial imagery from the South Island at Chase Lake suffer from underestimation due to undetected pelicans nesting under the tall shrubs. For example, observers counted 3,069 and 3,936 pelican nests under the shrub canopy of the subcolonies in 2012 and 2013,

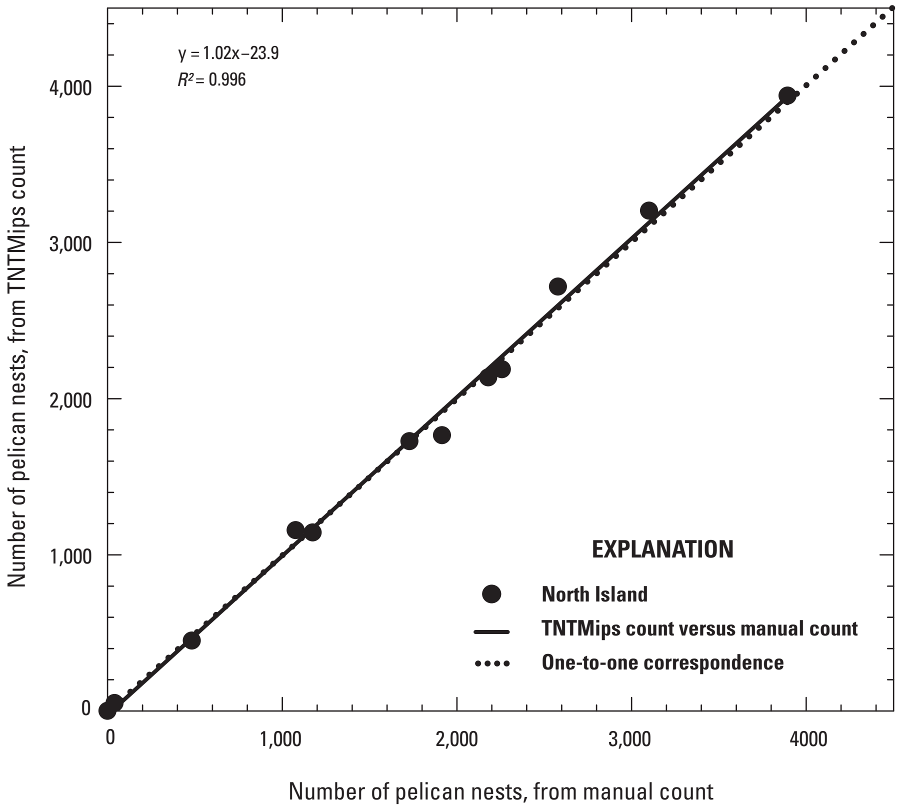

Figure 18. Regression analysis between manual counts of American White Pelican (*Pelecanus erythrorhynchos*) nests from aerial images and semiautomated remotely sensed counts using TNTMips software.

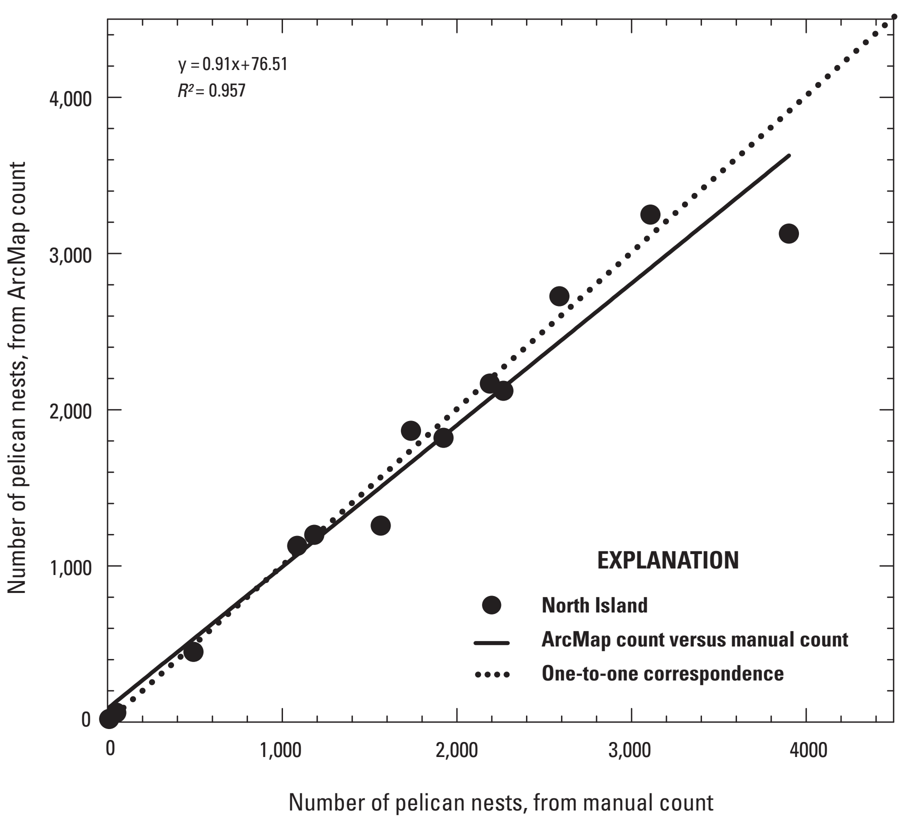

Figure 19. Regression analysis between manual counts of American White Pelican (*Pelecanus erythrorhynchos*) nests from aerial images and semiautomated remotely sensed counts using ArcMap software.

Table 8. Summary statistics from regression and inverse regression models comparing manual counts of American White Pelican (*Pelecanus erythrorhynchos*) nests and semiautomated counts of pelican nests by using remote-sensing software on the North Island at Chase Lake, 2001–13.

[*n*, sample size; β_0, y-intercept; SE, standard error; β_1, slope of the regression line; R^2, coefficient of determination; *y*, semiautomated count ("measured"); *x*, manual count ("truth"); MAD, mean absolute difference between original *x*-value and predicted new *x*-value; SD, standard deviation of the absolute difference; MD, mean difference in number of nests between original *x*-value and predicted new *x*-value]

Summary statistics	Semiautomated counting method	
	TNTMips	ArcMap
n	12	13
β_0 (SE)	−23.90 (41.47)	76.51 (116.92)
β_1 (SE)	1.02 (0.02)	0.91 (0.06)
Mean sum of squares	6,483.57	53,365
R^2	0.996	0.957
Mean *y*	1,705.8	1,612.2
Mean *x*	1,702.3	1,691.0
Corrected sums of squares of *x*	15,931,715	15,951,752
MAD (SD)	56.5 (47.2)	172.8 (164.2)
MD	−0.008	0.008

respectively. The issue of remotely surveying pelicans beneath the tall shrubs without disturbing them remains to be solved. Bakó and others (2014) recommended that within-colony ground observations of nests under trees and shrubs can be substituted in many cases. In recent years, nest estimates on the South Island at Chase Lake have included adjustments based on within-colony observations of nests beneath the shrubs.

Semiautomated counts may be more efficient than traditional manual counts for large pelican colonies. For the Chase Lake counts, the time spent preparing images for counting was longer for manual counts than semiautomated counts, but the time spent counting and processing was similar between the two approaches. Chabot and Francis (2016) reviewed the literature on recent advances in digital photography and image-analysis software for computer-automated detection and counts of birds on aerial images. They indicated that an automated approach may not be worthwhile if the approach requires more total time (especially in setup) than manual analysis of the images, but the authors acknowledged that the use of automated analysis may help avert repetitive motion syndrome resulting from tedious manual counts in large colonies and may reduce variation due to observer fatigue. Using a highly autonomous method, Descamps and others (2011) counted count nearly 40,000 Greater Flamingos (*Phoenicopterus roseus*) in five colonies in 1.63 hours compared with 24.25 hours for manual counts.

In summary, image processing analysis using remote-sensing software provides an accurate alternative to traditional manual counts of American White Pelican nests at Chase Lake, as well as a mechanism to monitor changes in distribution. Our results indicate that image processing analysis using remote-sensing software will have widespread value and provide an accurate method to obtain abundance estimates of nesting American White Pelicans at Chase Lake and other pelican colonies in the region. For Chase Lake, the regression and inverse regression model from this study can be used to predict the "true" counts from the semiautomated counts using TNTMips or ArcMap remote-sensing software. A benefit of digital-image processing is that permanent digital files can be developed for annual counts, a capability that may be beneficial in evaluating annual shifts in distribution of pelican subcolonies. The resolution of digital cameras continues to improve, which will enable detection of smaller species (Chabot and Francis, 2016), such as gulls at Chase Lake, and provide an alternative to manual nest counts for these species.

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Appendix 1. Estimates of the number of American White Pelican (*Pelecanus erythrorhynchos*) nests at Chase Lake National Wildlife Refuge, North Dakota, 1905–2017

Table 1.1. An update to Sovada and other's (2005) estimates of the number of American White Pelican (*Pelecanus erythrorhynchos*) nests at Chase Lake National Wildlife Refuge, North Dakota, 1905–2017.

[--, no data; ANWR, Arrowwood National Wildlife Refuge; CLNWR, Chase Lake National Wildlife Refuge; NPWRC, Northern Prairie Wildlife Research Center]

Year[a]	Original islands		Southeast peninsula and islands				Northwest peninsula	Estimated total number of nests	Source[b]
	Small Island	Large Island	North Island	Middle Island	Southeast Shore	South Island			
1905	--	--	--	--	--	--	--	250[c]	H.H. McCumber in Bennett, 1926
1908	--	--	--	--	--	--	--	25[c]	H.H. McCumber in Bennett, 1926
1911	--	--	--	--	--	--	--	48	H.H. McCumber in Stewart, 1975
1912	--	--	--	--	--	--	--	80	H.H. McCumber in Stewart, 1975
1914	--	--	--	--	--	--	--	100	H.H. McCumber in Stewart, 1975
1916	--	--	--	--	--	--	--	250[c]	Bennett, 1926
1917	--	--	--	--	--	--	--	111	H.C. Oberholser in Stewart, 1975
1924	--	--	--	--	--	--	--	1,250–1,500[c]	Bennett, 1926
1927	--	--	--	--	--	--	--	1,250–1,500[c]	H.H. McCumber in Stewart, 1975
1928	--	--	--	--	--	--	--	500	Bailey, 1935
1932	--	--	--	--	--	--	--	1,000–1,500[c]	Thompson, 1932
1937	--	--	--	--	--	--	--	200	Arrowwood National Wildlife Refuge, 1937
1941	--	--	--	--	--	--	--	150[c]	Lies and Behle, 1966
1942	--	--	--	--	--	--	--	23[c]	Lies and Behle, 1966
1943	--	--	--	--	--	--	--	138[c]	Lies and Behle, 1966
1944	--	--	--	--	--	--	--	750	Lies and Behle, 1966
1945	--	--	--	--	--	--	--	600[c]	Lies and Behle, 1966
1946	--	--	--	--	--	--	--	500	Lies and Behle, 1966
1947	--	--	--	--	--	--	--	400	Henry, 1947; Lies and Behle, 1966
1948	--	--	--	--	--	--	--	550[c]	Lies and Behle, 1966
1949	--	--	--	--	--	--	--	1,500[c]	Lies and Behle, 1966
1954	--	--	--	--	--	--	--	3,000[c]	N.B. Nelson in Stewart, 1975
1959	--	--	--	--	--	--	--	3,500	Lies and Behle, 1966
1960	--	--	--	--	--	--	--	500	Lies and Behle, 1966
1961	--	--	--	--	--	--	--	4,000	Lies and Behle, 1966
1963	--	--	--	--	--	--	--	4,000	Lies and Behle, 1966
1964	--	--	--	--	--	--	--	4,000[c]	Lies and Behle, 1966
1965	--	--	--	--	--	--	--	4,000[c]	D.A. Anderson in Stewart, 1975
1966	--	--	--	--	--	--	--	"numerous"	Stewart, 1975

Table 1.1. An update to Sovada and other's (2005) estimates of the number of American White Pelican (*Pelecanus erythrorhynchos*) nests at Chase Lake National Wildlife Refuge, North Dakota, 1905–2017.—Continued

[--, no data; ANWR, Arrowwood National Wildlife Refuge; CLNWR, Chase Lake National Wildlife Refuge; NPWRC, Northern Prairie Wildlife Research Center]

Year[a]	Original islands		Southeast peninsula and islands				Northwest peninsula	Estimated total number of nests	Source[b]
	Small Island	Large Island	North Island	Middle Island	Southeast Shore	South Island			
1967	--	--	--	--	--	--	--	3,000	ANWR, 1966
1970	1,230	2,438	--	--	--	--	--	3,668	ANWR, 1970
1971	--	--	--	--	--	--	--	2,150	Boeker, 1972; Sloan, 1973
1972	1,567	3,260	--	--	--	--	--	4,827	Strait, 1973; Johnson, 1976; Sidle and Ferguson, 1982
1973	1,880	2,031	--	--	--	--	--	3,911	Johnson and Sloan, 1978; Sidle and Ferguson, 1982
1974	1,891	1,191	--	--	--	--	--	3,082	Johnson and Sloan, 1978; Sidle and Ferguson, 1982
1975	2,456	1,765	--	--	--	--	--	4,221	Johnson, 1976; Sidle and Ferguson, 1982
1976	1,849	2,906	--	--	--	--	--	4,755	Lingle, 1977; Sidle and Ferguson, 1982
1977	931	3,688	--	--	--	--	--	4,619	Lingle, 1977; Sidle and Ferguson, 1982
1978	659	3,930	--	--	--	--	--	4,589	Sidle and Ferguson, 1982
1979	383	3,668	--	--	--	--	--	4,051	Sidle and Ferguson, 1982
1980	1,371	4,771	--	--	--	--	--	6,142	Sidle and Ferguson, 1982; Sidle and others, 1984
1981	1,544	4,282	--	--	--	--	--	5,826	Sidle and others, 1984
1982	1,389	3,879	--	--	--	--	--	5,268	Sidle and others, 1984
1983	2,253	3,039	--	--	--	--	--	5,292	Sidle and others, 1984
1984	1,331	2,590	--	--	--	--	--	3,921	CLNWR, 1984
1985	--	--	--	--	--	--	--	--	No survey conducted; CLNWR, 1985
1986	2,087	2,908	--	--	--	--	--	4,995	CLNWR, 1986
1987	1,856	5,283	--	--	--	--	--	7,139	CLNWR, 1987
1988	3,100	5,540	--	--	--	--	--	8,640	CLNWR, 1988
1989	2,313	4,316	--	--	--	--	--	6,629	CLNWR, 1989
1990	1,824	3,960	--	--	--	--	--	5,784	CLNWR, 1990
1991	--	--	--	--	--	--	--	--	No survey conducted; CLNWR, 1991
1992	2,564	3,412	--	--	--	--	--	5,976	CLNWR, 1992
1993	3,472	5,081	--	--	--	--	--	8,553	CLNWR, 1993
1994	4,308	4,237	--	--	--	--	--	8,545	CLNWR, 1994

Table 1.1. An update to Sovada and other's (2005) estimates of the number of American White Pelican (*Pelecanus erythrorhynchos*) nests at Chase Lake National Wildlife Refuge, North Dakota, 1905–2017.—Continued

[--, no data; ANWR, Arrowwood National Wildlife Refuge; CLNWR, Chase Lake National Wildlife Refuge; NPWRC, Northern Prairie Wildlife Research Center]

Year[a]	Original islands		Southeast peninsula and islands				Northwest peninsula	Estimated total number of nests	Source[b]
	Small Island	Large Island	North Island	Middle Island	Southeast Shore	South Island			
1995	1,797	3,888	3,495	--	--	--	--	9,180	CLNWR, 1995
1996	585	539	8,657	--	--	--	--	9,781	CLNWR, 1996
1997	38	--	9,144	--	--	--	--	9,182	CLNWR, 1997
1998	61	--	7,755	--	4,465	--	--	12,281	CLNWR, 1998
1999	--	3	1,474	--	--	--	13,318	14,795	CLNWR, 1999
2000	--	--	3,073	--	2,937	--	11,723	17,733	CLNWR, 2000
2001	--	--	2,187	338	--	--	12,371	14,896	CLNWR, 2001
2002	--	--	3,939	1,491	--	792	10,661	16,883	CLNWR, 2002
2003	--	--	1,727	503	--	6,922	6,501	15,653	CLNWR, 2003
2004[d]	--	--	--	--	--	--	--	--	No survey conducted; NPWRC
2005	--	--	1,682	153	--	7,590	--	9,425	NPWRC
2006	--	--	3,202	--	--	14,100	--	17,302	NPWRC
2007	--	--	1,157	--	--	10,105	--	11,262	NPWRC
2008	--	--	2,716	--	--	8,825	--	11,541	NPWRC
2009	--	--	2,135	--	--	5,101	--	7,236	NPWRC
2010	--	--	1,142	--	--	8,451	642	10,235	NPWRC
2011	--	--	418	--	--	9,309	--	9,727	NPWRC
2012	--	--	--	--	--	16,245	--	16,245	NPWRC
2013	--	--	50	--	--	15,953	--	16,003	NPWRC
2014	--	--	--	--	--	17,073	--	17,073	NPWRC
2015	--	--	--	--	--	17,249	--	17,249	NPWRC
2016	--	--	--	--	--	16,847	--	16,847	NPWRC
2017	--	--	--	--	--	13,560	--	13,560	NPWRC

[a]Little information was available regarding how estimates were determined prior to 1970; systematic annual surveys of nest numbers began in 1972; nest numbers between 1980 and 2017 were determined from aerial photographs.

[b]Annual reports (Arrowwood National Wildlife Refuge, 1937–1985; Chase Lake National Wildlife Refuge, 1986–2003) were examined to corroborate published reports.

[c]Published accounts indicated number of breeding adults. That number was divided by two for estimation of the number of nests.

[d]Nearly all nesting adult pelicans deserted their nests at the Chase Lake colony in late May and early June 2004, prior to the scheduled aerial survey (Sovada and others, 2014).

Table 1.2. Estimates of the number of nests of American White Pelicans (*Pelecanus erythrorhynchos*) from aerial photographs taken on the North Island (2011–2013), Middle Island (2003 and 2005), South Island (2003 and 2005), and all islands and peninsulas (1992, 1998, and 2015) at Chase Lake National Wildlife Refuge, North Dakota, based on traditional manual counts and counts from digital-image analysis using TNTMips geographical information system.

Year	Island	American White Pelican	
		Manual	**TNTMips**
1992	All	5,976	5,886
1998	All	12,281	13,205
2001	North	2,258	2,187
2002	North	3,894	3,939
2003	North	1,728	1,727
2003	Middle	503	429
2003	South	6,546	6,922
2005	North	1,915	1,765
2005	Middle	153	179
2005	South	7,590	7,387
2006	North	3,101	3,202
2007	North	1,077	1,157
2008	North	2,579	2,716
2009	North	2,180	2,135
2010	North	1,174	1,142
2011	North	482	450
2012	North	0	0
2013	North	40	50
2015	All	13,013	13,249

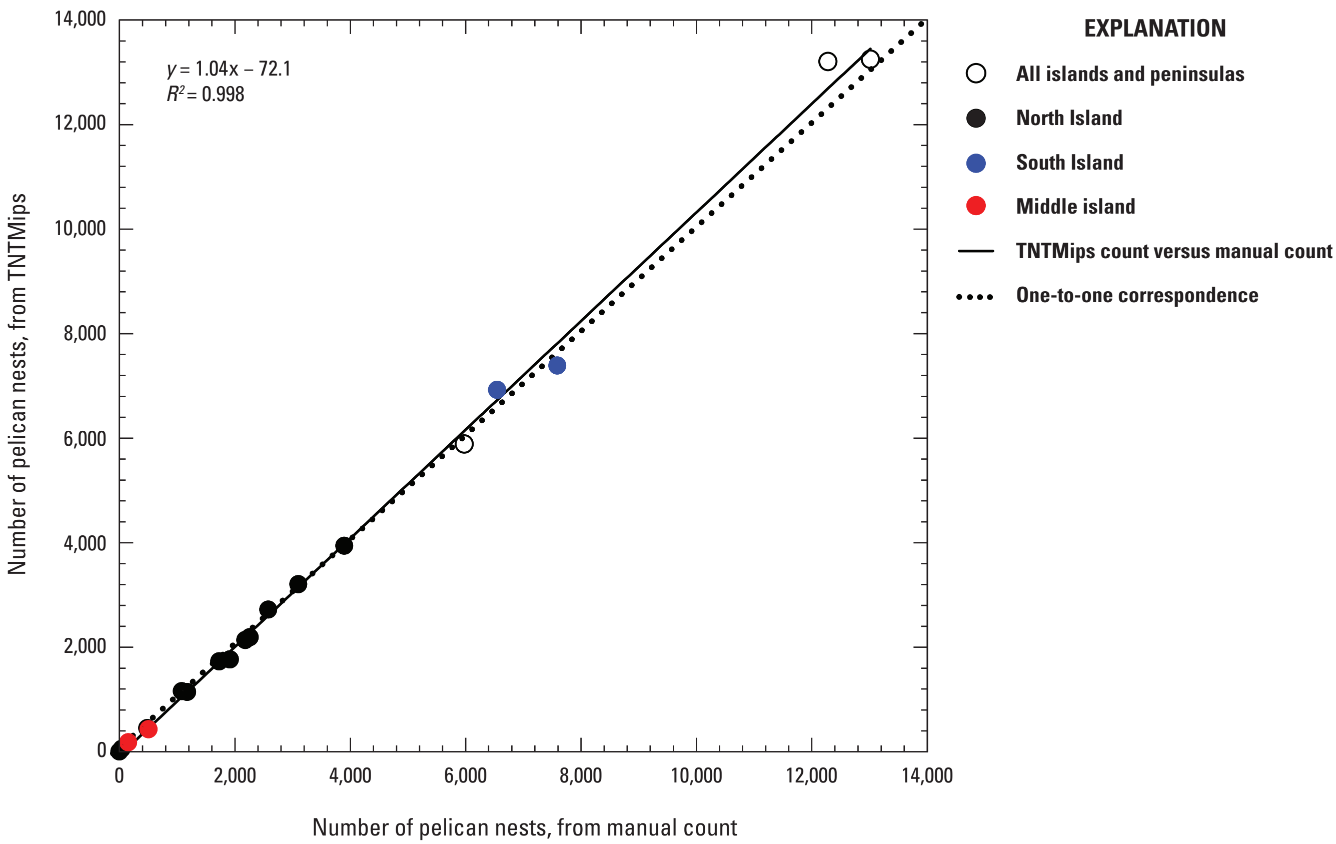

Figure 1.1. Regression analysis between manual counts of American White Pelican (*Pelecanus erythrorhynchos*) nests from aerial images and semiautomated remotely-sensed counts using TNTMips software on the North Island (2011–2013), Middle Island (2003 and 2005), South Island (2003 and 2005), and all islands and peninsulas (1992, 1998, and 2015) at Chase Lake National Wildlife Refuge, North Dakota.

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