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Ecology of the Great Blue Heron (*Ardea herodias*) rookery on the Slate River, Crested Butte, Colorado and impacts of human activities

2018 Pilot Study

Final Report
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"From its form and color, as well as size, it was singularly distinct….

They stood in the midst of the open river, on this shallow and reedy bar in the sun, the leisurely sentries, lazily pluming themselves, as if the day were too long for them. They gave a new character to the stream. Adjutant they were to my idea of the river, these two winged men….

How long we may have gazed on a particular scenery and think that we have seen and known it, when, at length, some bird or quadruped comes and takes possession of it before our eyes, and imparts to it a wholly new character. The heron uses these shallows as I cannot. I give them up to him."

Henry David Thoreau 1859

Photo by Carley Clegg

EXECUTIVE SUMMARY

The Great Blue Heron (*Ardea herodias*) has flapped its immense wings and cast its shadow over North America's wetlands for nearly two million years. The large heron spends much of its life as a solitary hunter, but in spring these birds join gregarious breeding colonies and nest in the crowns of trees. One such heronry, in the Slate River wetlands adjacent to Crested Butte, Colorado, has persisted for a couple decades and hosts a large number of active nests. Herons choose colony sites based on energetic profitability and isolation from human disturbance or predation and a colony location represents a unique combination of eco-geographic characteristics that are limited across the landscape. This heronry is unique in its high elevation, occurrence in coniferous trees, large size (>20 nests), and its long-term persistence. The Crested Butte Land Trust (CBLT) owns and manages the property containing the heronry and they face a challenging management dilemma to balance their values of protecting ecological integrity and providing human access. Outdoor recreation is an important foundation for Crested Butte's way of life and economic vitality. In recent years, human activities in the Crested Butte area have increased dramatically and include novel sports such as stand up paddle (SUP) boarding. River recreation and other forms of pedestrian based activities represent a significant disturbance threat to the Great Blue Heron rookery. The purpose of our pilot study was to collect baseline data on the timing of breeding events and demographic characteristics of the heronry. We also documented heron activity budgets and assessed impacts of human activities on heron behaviors during the 2018 nesting season.

Great Blue Herons arrived at the Slate River colony site on 13 March 2018 to begin the breeding season. Egg laying and incubation were initiated around 9 April. The first chicks hatched around 7 May and last hatch was 23 June. The first fledged chick left the nest on 3 July and the last chick flew on 15 August. Chicks and adults vacated the Slate River wetlands in the immediate vicinity of the heronry as soon as juveniles fledged. Adults spent most of their time in the nests brooding young, preening feathers and conducting other comfort activities, and incubating eggs. Juveniles spent 87% of their time in self-maintenance and 9% in vigilance. In wetlands, adults spent 61% of their time foraging and 26% in self-maintenance behaviors. Age, time of day, season, and habitat influenced heron activity budgets.

We documented 3,520 human activities in 59 1-hour observation bouts in the vicinity of the Slate River heronry. Most of these were on the Slate River Road and most were greater than 250-300 m from the heronry. River recreation comprised less than 1% of the total events, but watercraft were linked to 95% of adult flush events that left nests unattended for a mean of 4 minutes. Rivercraft were associated with 65% of adult heron alert behaviors indicating disruption of normal behavior and increased stress.

The Slate River Great Blue Heron rookery is a unique ecological component of regional biodiversity and due to its relatively large size likely contributes to regional population stability of Great Blue Herons. More data are needed to better assess variations in heron numbers and nesting characteristics among years and to fill in gaps early in the season. Based on our observations and the clear body of evidence from numerous research studies of pedestrian-based recreation in close proximity to heronries, effective protection of the heronry should consider restricting human activities throughout the breeding season from 15 March to 15 August to a distance of 300 m from the colony. Colony abandonment could be related to altered habitat (foraging opportunity, changes in predator populations, and nest tree health and availability) and human disturbance, the latter being controllable by management decisions.

Photo by Noppadol Paothong

Ecology of the Great Blue Heron rookery on the Slate River, Crested Butte, Colorado and impacts of human activities

INTRODUCTION

North America's wading birds consist of a group of large, semi-aquatic species that characteristically nest in colonies. The Great Blue Heron (*Ardea herodias)* is the largest member of this group and has existed on earth for 1.8 million years (Vennesland and Butler 2011). Due to their large size, elaborate plumage and colonial nesting habit, many herons and egrets, among many bird species, were exploited at the turn of the 20th Century, primarily for their feathers (Merchant 1984). The millinery industry thirsted for prominent plumes to decorate women's hats and heron feathers were valued at $32/ounce in 1903 (Ehrlich et al. 1988), compared to $20/ounce for gold. The plume trade resulted in millions of birds killed annually (5 million in 1886 according to the American Ornithologist's Union) and, in 1902, 192,960 adult herons were killed plus 2-3x that number of eggs and chicks; the heron plumes were worth $1.5 million (Ehrlich et al. 1988). Fortunately, the overexploitation of birds for the millinery industry eventually ignited the effort for comprehensive bird protection and in 1918 the Migratory Bird Treaty Act passed and ended numerous forms of "take" including plumes for women's hats (Moore-Colyer 2000).

Today, Great Blue Heron population trends are largely stable to positive (Vennesland and Butler 2011). According to Breeding Bird Survey data across their range Great Blue Herons have experienced positive growth over the last 50 years (Sauer et al 2017). However, in the Western BBS region, Great Blue Heron populations have declined over the last 50 years, although that trend has stabilized in the last 10 years (Sauer et al. 2017). The current population estimate for Great Blue Herons in North America is 124,000 (Sauer et al. 2017). In Colorado, the number of Great Blue Heron colonies seems to be increasing, although mean colony size is smaller than in the late 1990s (Brown and Dexter 2016).

Region	Trend	1966-2015	2005-2015
U.S.	**Significantly increasing**	**+0.87% (0.63, 1.11)**	**+1.12% (0.38, 1.97)**
Western Region	**Significantly decreasing**	**-0.79% (-1.31, -0.30)**	**-0.47% (-1.64, 0.66)**
Colorado	**Stable**	**1.10% (-0.42, 2.70)**	**-1.27% (-5.99, 2.66)**

Data represent the percent change annually with 95% confidence intervals in parentheses. Data from Sauer et al. 2017.

Great Blue Heron Annual Cycle and Life History

Throughout most of the year solitary Great Blue Herons defend feeding territories. During the breeding season, however, they nest gregariously in colonies (called heronries or rookeries) that are often located (almost always in Colorado) in the crowns of trees (Brown and Dexter 2016). Colonial nesting is

energetically beneficial where food supplies are centrally located near the heronry (Gibbs 1991). Males arrive on traditional breeding grounds in early spring and claim and defend a nest site; they often reuse old nests and the colony may return for decades to long-established heronries (Mock 1976, Vennesland 2000, Corley-Martinez 1995). Females follow about a week later (Vennesland 2000) and for several weeks, herons court, form pair bonds and begin nest building. All of this activity is steeped in tradition and elaborate displays (Vennesland 2000). The male eventually allows a female to enter his nest and after complex bill fencing and stick displays the pair forms. Males often gather sticks and, in ritualized fashion, hand them off to females to place in the nest (Mock 1976). Soon copulation occurs and females begin laying eggs and produce mean clutch sizes varying from 2-6 eggs (Vennesland and Butler 2011). In the case of nest loss, female herons may lay a second clutch (Vennesland and Butler 2011). After the first egg is laid the incubation stage begins but subsequent eggs continue to be laid at one and a half to two day intervals. Incubation lasts approximately 27-29 days (Pratt 1970, Mock 1978) and males and females split incubation duties with males taking most of the day shift (10 hours per day) and females incubating at night (Brandman 1976). Eggs remain concealed in parental plumage absorbing heat for 54 minutes per hour during the month-long "gestation" period (Pratt 1970).

Chicks hatch asynchronously in a semi-altricial state (Ehrlich et al. 1988). Wide-eyed and covered in down, they may vocalize immediately after hatching. Nonetheless, they depend completely on parents for food, remaining imprisoned in their nests for seven weeks or more (Vennesland and Butler 2011). The first hatched young often survives better than subsequent nest mates, and gains a distinct size and strength advantage over siblings when food is delivered to the nest (Vennesland and Butler 2011). During the early nestling stage, one adult typically forages while the other broods the young. Feeding activity peaks at 4 weeks (Butler 1992) and the nestlings require more food resulting in both adults leaving the nest to forage (Mock 1976). Adult presence in the nest drops from about 83 - 99% of their time spent in the nest at hatch time to almost 0% at 6 to 7 weeks old (Butler 1992). Rearing fast growing young (they reach 86% of adult's mass in 45 days) is demanding on parents who eat 4 times more food during the nestling stage than during incubation (4,300 KJ/day during nestling stage vs. 1,200 KJ/day during incubation; Butler 1991). Chicks take flight between 49-81 days, with shorter nestling periods at the northern extreme of their range (Vennesland and Butler 2011). After the first flight, chicks may remain nearby the nests for three more weeks, still accepting food from the parents (Vennesland and Butler 2011). Following fledging, herons may disperse over 700 km in many directions (Melvin et al. 1999), or they may remain in the vicinity of the heronry and migrate to wintering grounds by October (Vennesland and Butler 2011).

> *"Their profuse ordure [and] the decaying fish which fall from the nests make a heronry far from pleasant,"*
>
> *Arthur Cleveland Bent*

Great Blue Heron Human Disturbance

Human activities such as biking, running, hiking, birding, river floating and many other pursuits potentially have negative effects on wildlife abundance, occupancy, reproductive success, behavior, stress level, and ability to raise young (Ikuta and Blumstein 2003). Several researchers have studied the effects of human disturbance on Great Blue Heron rookeries (Parker 1980, Taylor et al. 1981, Vos et al. 1985,

Hockin et al. 1992, Klein 1993, Corley-Martinez 1995, Carlson and McLean 1996, Vennesland 2000, Vennesland and Butler 2004, Vennesland 2010). The impact of human activities on herons depends on the type, timing, frequency and the magnitude of the disturbance as well as site factors and does not always translate into population-level impacts (Nisbet 2000). However, human activities, including recreation, have been tied to a reduction in Great Blue Heron reproductive success (Carlson and Mclean 1996, Vennesland 2000, Vennesland and Butler 2004). Specifically, human disturbances have disrupted heron nesting behaviors and foraging, and have increased vulnerability of eggs and hatchlings to predation and weather events (Vos et al. 1985, Parnell et al. 1988, Klein 1993) and have resulted in higher egg and nestling mortality, reduced body mass, slower growth, premature fledging, and nest abandonment (Vos et al. 1985, Rodgers and Smith 1995, Machmer and Steeger 2004). Off the nest, disturbances result in reduced foraging time and efficiency (Machmer and Steeger 2004). Herons are more sensitive to disturbance early in the nesting period and are more likely to abandon a site at this time (Parnell et al. 1988, Vennesland 2000). In Montana, herons abandoned a colony and moved to a more isolated site16 km away due to increased river use by recreationists (Parker 1980). One site was abandoned when 150 people canoed past the colony in one day (Parker 1980). Visual disturbances elicited stronger reactions by herons than sound disturbances (Taylor et al. 1981). Some studies reported habituation by herons to non-threatening human disturbance but in these studies, tolerance of human activity occurred later in the nesting cycle or when disturbances were distant from the colony (Hockin et al. 1992). In a two-year study, heron response was not consistent among years, increased in late nesting in the second year, and was coupled to additive local stressors (Vennesland 2000).

Great Blue Heron Vulnerability to Disturbance	
Nesting	**Feeding**
Colonial nesting, all nests in a single location	Foraging space limited and spatial arrangement of foraging sites relative to colony
Nest site fidelity, return to same site for consecutive breeding seasons	Patient stand-in-wait method (requires long undisturbed foraging bouts)
Long duration of nest season and large investment of time and energy in each chick, slow development	Foraging locations may be spatially separate from nesting habitat
Specialized habitat needs (crowns of tall riparian trees)	Highest annual daily energy requirements for adults during chick rearing
	Adults provision chicks more than 10 times per day

Increased river recreation on the Slate River in Crested Butte, Colorado in recent years has led to concerns about a Great Blue Heron rookery at the site. The site is owned and managed by the Crested Butte Land Trust (CBLT) with a mission of protecting the ecological values of the Slate River wetlands and simultaneously they encourage outdoor recreation and use of their protected lands. Like many land managers (Gill 2007), the CBLT faces a dilemma regarding how to balance competing values. The rookery is located in a stand of blue spruce trees growing on the banks of the Slate River. Watercrafts such as canoes, kayaks, rafts, duckies and stand up paddle boards, along with pedestrian recreationists such as anglers and cross-country skiers along this stretch of the Slate River would approach the heron colony at very close distances. Great Blue Herons are particularly wary (Vos 1et al. 985) and vulnerable to disturbance. The purpose of this study was to document baseline heron use, the magnitude of human activities and response by herons to human activities.

Research Objectives

The purpose of this study was to observe and document life history, breeding phenology, and population demography of the Great Blue Heron colony at the Slate River heronry in Crested Butte, Colorado. Further, we quantified heron activities at the nest colony and documented human disturbances and heron responses to human activities. More specifically we addressed the following four research objectives:

1. Phenology of Great Blue Heron breeding activities

Document the annual cycle phenology from spring arrival to fall departure of Great Blue Herons with focus on the breeding season. We determined the timing and duration of the following annual cycle events:

- Spring migration arrival to nest colony
- Nest selection and building
- Courtship and mating
- Egg laying and incubation
- Nestling stage and fledging dates
- Fall migration departure from colony

2. Demographic characteristics of Great Blue Heron breeding

Identify basic demographic characteristics of the Slate River heron colony including

- Number of nests (number occupied)
- Number of herons
- Number of nests with eggs (incubation)
- Number of successful nests (at least one egg hatches)
- Number of chicks produced
- Number of chicks fledged

3. Quantify Great Blue Heron behavior within the colony

Document heron activity patterns during incubation and brood rearing including male and female nest attendance, movements and locations of Great Blue Herons away from nests and in foraging locations. Data were gathered using two foundational techniques in animal behavior studies. Scan sampling surveyed the entire colony within a short observation bout to determine the average behavior of adult birds. In contrast, focal time budgets were used for more detailed observations of adult and juvenile herons in and out of the nest. We assessed the Great Blue Heron behavior in relation to time of day and relative to season.

4. Quantify human activities and potential disturbances to the Great Blue Heron colony

We conducted observations of human activities in the vicinity of the Great Blue Heron rookery on the Slate River. In addition to quantifying and classifying activities, we observed heron responses to each activity to assess potential human disturbance to the birds.

METHODS

Study Area

The Great Blue Heron nesting colony (heronry or rookery) is located along the upper Slate River adjacent to Crested Butte, in Gunnison County, Colorado (Figure 1). The heronry resides on land owned by the CBLT (0326280E 4306913N), but the wider landscape represents a mosaic of landownership that includes the Bureau of Land Management (BLM), the USDA Forest Service (USFS), CBLT, private properties with conservation easements (held by CBLT and the town of Crested Butte), small sub-divisions including the Wildbird property, and other private land (Slate River Working Group 2018). Access to the Slate River is available to the public at two locations above the heronry at the Oh-Be-Joyful campground under BLM management and at the Gunsight Bridge owned by CBLT with an access easement held by the town of Crested Butte (Slate River Working Group 2018). The CBLT mission includes protection of ecological resources and public access.

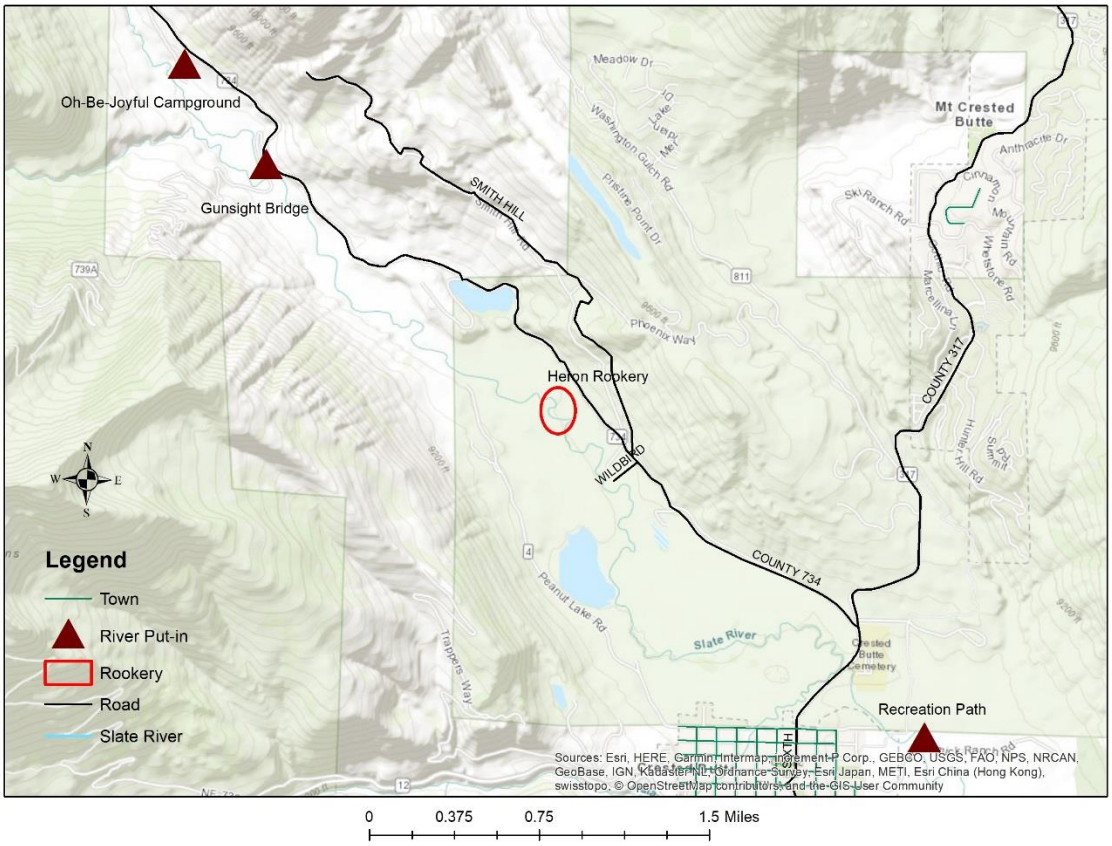
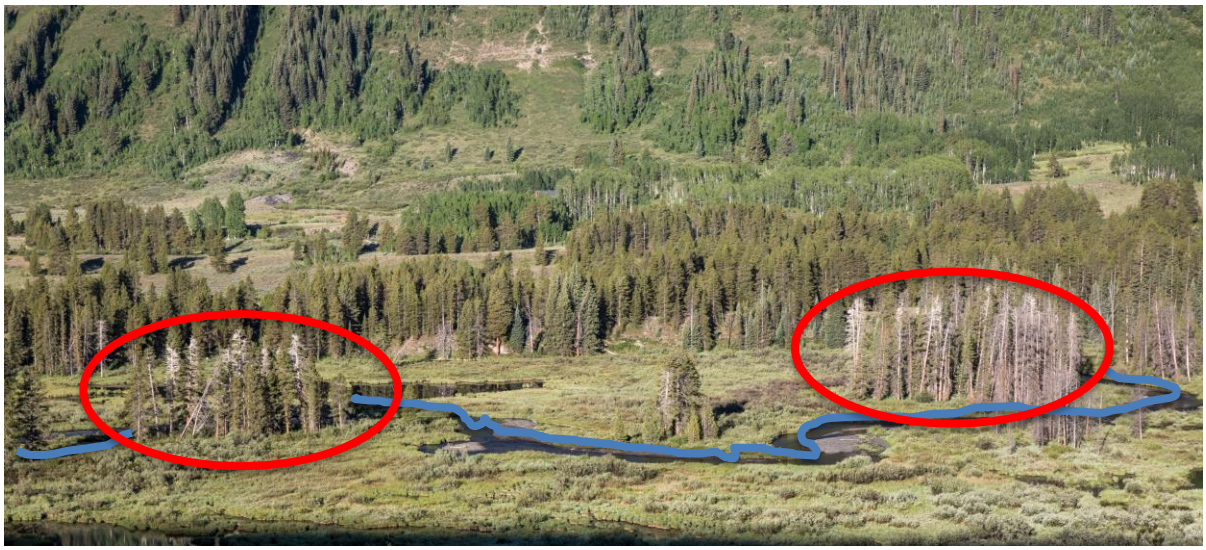


Figure 1. Slate River wetlands and Great Blue Heron colony adjacent to Crested Butte, CO.

The heronry is located in two stands of Blue Spruce (*Picea pungens*) with many of the trees partially or fully dead – likely as a result of heron occupancy of the site for at least 20 years (their feces and prey remains spilling out of the nests located in the tree crowns eventually kill foliage). The colony trees hover along the banks of the Slate River which winds its way across the u-shaped, glacial valley demarcated by glacial moraines (Cooper 1993). The low gradient stream meanders across the valley bottom and over time has created a diverse wetland complex characterized by the active stream channel, historic channels, oxbow lakes, and beaver ponds. All of these aquatic habitats provide potential foraging areas for Great Blue Herons and host a variety of mammal and bird species (see Appendix). In addition to the riparian spruce trees, vegetation includes a mix of woody (especially willow) and herbaceous wetland plant species.



The Slate River (indicated by blue line) flows from right to left in the photograph with the Upper Colony on the right and the Lower Colony is circled on the left. These two Great Blue Heron colonies are directly adjacent to the Slate River. Photo by Carley Clegg.

Study Design and Data Collection

Great Blue Heron phenology

We documented Great Blue Heron breeding season phenology by making nest and bird counts beginning 14 March and ending on 13 August 2018. Detailed observations using a spotting scope began on 15 May and we visited the heronry approximately five days per week. We observed the colony from three observation points: above the colony on Smith Hill Road to the east, on the Slate River Road (about 300 m from the colony) also to the east, and on the Wildbird ridge to the west of the colony (about 200 m from the colony). During observations we recorded time, date, weather, presence of herons (adults and chicks), and heron behaviors that indicated the annual cycle event. Specifically we documented first arrival date of herons (spring migration), beginning of nest building and courtship, timing of incubation (based on presence of herons sitting low in the nest), hatch dates (first observation of chicks in nest), and end of nestling stage indicated by fledging (date chicks departed the nest). We were able to back date the initiation of egg laying and incubation from knowledge of incubation length (27-29 days, Vennesland and Butler 2011). We intended to continue observations of herons at the colony site post-fledging to determine timing of fall migration and/or dispersal, but most herons departed the Slate River valley almost immediately after fledging (adults and juveniles).

Great Blue Heron nesting demographics

We gathered demographic data of each nest in the colony. We identified the location of each nest on a photograph and gave each a unique number. During visits we conducted a systematic scan of all the nests and counted the number of adults, the number of nests with incubating adults (indicates eggs present), the number of successful nests (proportion of nests with at least one successfully hatched egg – nest success), the number of chicks produced (brood size), the number of nests that produced at least one successful fledge (fledging success), and the number of chicks that fledged (fledgling success).

Time activity budgets

We recorded behaviors of Great Blue Herons using two distinct time budget methods, scan and focal sampling (Altmann 1974). During the incubation and brood rearing periods, we quantified heron activity budgets three days each week, rotating observation times among three 5-hour periods. We conducted morning observations from approximately 500 to 1000, day time observations occurred from 1000 to 1500, and evening observations were from 1500 to 2000.

We employed scan sampling to record behavior of every adult heron present at the rookery and quantified the proportion of the "flock" engaged in each behavior at one moment in time. We began with nest number one and systematically scanned each nest recording the number of adult herons in the nest and an associated behavior for each heron. We did not record juvenile behaviors during scan sampling.

We performed focal time budgets on randomly selected herons (adults and juveniles) as well as empty nests. We observed empty nests to quantify nest occupation. We recorded behavior every 30 seconds for 20 minutes and used a timer to indicate intervals and end time. In addition to adult and juveniles in nests, we also observed herons in the wetland habitat when a bird was present. We identified 34 potential heron behaviors in 8 broad categories (Table 1).

Table 1. Eight behavior categories used to quantify Great Blue Heron time activity budgets at the Slate River heronry in 2018.

Behavior Category	Behaviors	Description of Behavior
Foraging	5 foraging behaviors	All activities associated with catching, handling and consuming food
Locomotion	2 locomotion behaviors	Walking and flying
Self-maintenance	7 self-maintenance behaviors	Preening, stretching, sun-bathing, thermal control, sleeping, roosting, standing in nest, nest maintenance
Agnostic	5 agnostic behaviors	Intra- or interspecific aggression
Courtship and mating	11 courtship behaviors	Male to male, or male to female communication performed during pair formation and nest building. These behaviors may continue for the duration of the pair bond and nesting season
Alert/Vigilant	1 vigilant behavior	Heron responding to external stimuli indicating heightened awareness
Incubation	1 incubation behavior	Adult males and females take turns incubating eggs
Brooding	2 brooding behaviors	Adults attend to and feed chicks

Human activities and heron disturbance

We quantified human activities within 400 m of the heronry through one-hour long observation bouts. Most of these observations were made from the Smith Hill Road observation point which provided an "aerial" view of the landscape, including a fairly clear view of the Slate River upstream and downstream of the colony. During this time we recorded all human activities on the Slate River Road, on other roads and trails, in the aerial environment overhead, in the wetlands, and on the Slate River. Disturbances were categorized into eight types including cars/trucks, bicycles, dirt bikes/ motorcycles/four-wheelers, hikers/runners, airplanes/helicopters, alarms, livestock, and river recreation (watercrafts). We recorded the location and duration of the human activity, the number of people associated with each event (where practical – challenging or impossible to count number of people in vehicles or airplanes), and heron behavior and response to activities. To do this we scanned the colony prior to the observation bout to assess baseline behavior and scanned again during the human activity. We recorded the number of herons exhibiting disturbance behaviors which included alert posture and/or flushing from the nest.

Data Analyses

In this pilot study our aim was to collect baseline data to characterize the Slate River heronry and thus we employed descriptive statistics to quantify heron phenology, nesting demography and time activity budgets. In some cases we compared heron counts or activity budgets with inferential tests (ANOVA for three-way comparisons and t-test for two-way comparisons) using Microsoft Excel. For these hypothesis tests we used an alpha value of 0.05 to judge statistical significance. We conducted ANOVA to compare behaviors among morning, day, and evening periods. T-tests were used to compare behaviors for wetland versus nest, adult versus juvenile, and incubation versus nestling stage.

Drawing by Kenley Jones

RESULTS

We observed the Great Blue Heron colony at Slate River on 80 days during the 155 day period of heron occupancy from 13 March to 15 August 2018. Our effort focused on the period from 8 May to 13 August (94 days). During this period Megan Zareba observed the colony on 70 days. Pat Magee added 10 days of observation from 14 March to 25 May. We committed 550 hours to the project and drove 1,460 miles.

Great Blue Heron nest identification

We counted 26 nests in two sub-colonies. Each nest was numbered and individually monitored throughout the 2018 breeding season (Figures 2 and 3).

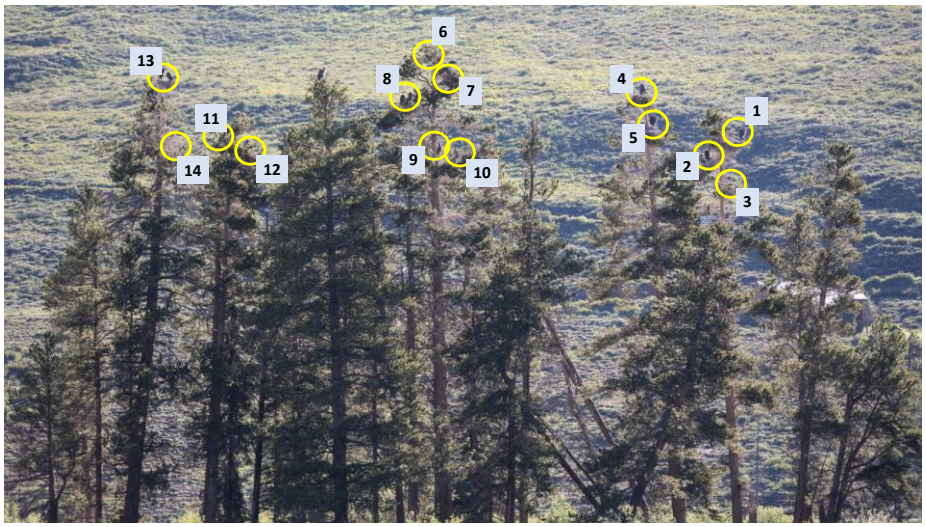


Figure 2. Identification of 14 Great Blue Heron nests in the lower colony in the Slate River wetlands in Crested Butte, CO in summer 2018. Photo by Carley Clegg from Wildbird ridge.

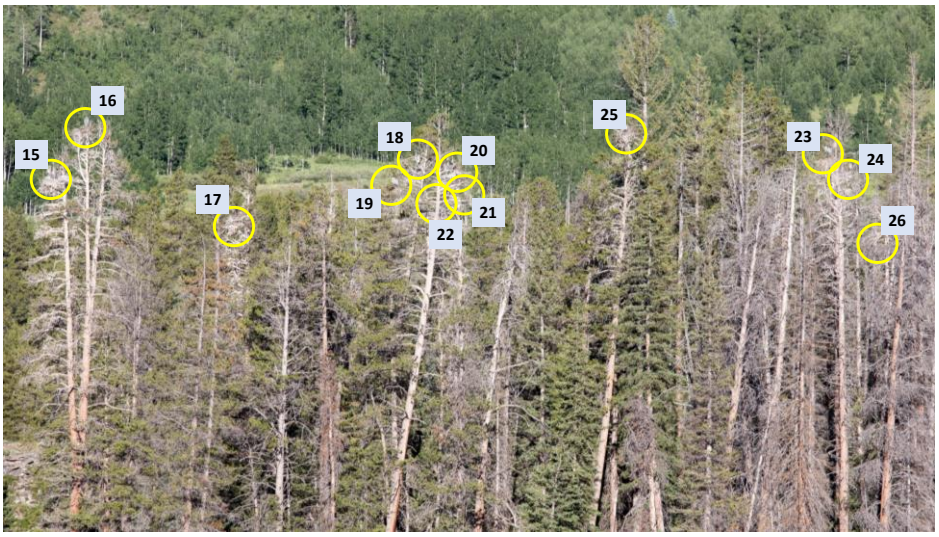


Figure 3. Identification of 12 Great Blue Heron nests in the upper colony in the Slate River wetlands in summer 2018. Nest 23 was the only inactive nest in 2018. Photo by Carley Clegg from Slate River Road.

Phenology and demography of Great Blue Heron breeding activities

The first heron arrived at the Slate River heronry on 13 March 2018 before the formal start of our study and we did not record dates of individual heron arrivals. The Slate River and the associated wetlands were still mostly frozen and snow covered through the end of March and into early April, despite the low snowfall winter. By 30 March copulatory behavior was observed (Table 2). The last heron fledged by 15 August and the colony was empty – few birds remained in the area post-fledging. Heron nesting is not synchronized so annual cycle events overlap among colony members.

Table 2. Annual cycle of breeding events for Great Blue Herons at the Slate River heronry in 2018.

Life cycle event	2018 dates	
Spring migration, Arrival	13 March	**Mid-March to Mid-August (155 Days)**
Gathering Grounds	Not observed	
Pair formation	No data	
Nest building	13 March – ?, No data	
Egg laying	9 April – 21 May (6 weeks)	
Incubation/Egg Stage	9 April – 23 June (10 weeks)	
Hatching	7 May – 23 June (7 weeks)	
Brooding/Nestling Stage	7 May – 15 August (15 weeks)	
Fledging	3 July – 15 August (7 weeks)	
Fledgling Stage	Fledglings largely disappeared immediately after fledging	
Second Broods	None observed	
Fall migration/Departure	Adults and fledglings departed the Slate River wetlands soon after fledging. We do not have data on their locations.	
The first Great Blue Herons were observed on 13 March 2018. The first observed chick in the nest was 9 May (but the nest had two chicks, so the first chick likely hatched two days earlier on 7 May). The incubation length of GBHE is 27-29 days (Vennesland and Butler 2011), therefore, by back dating from hatch date, egg laying/incubation began on approximately 9 April. The last nest hatched its first of two checks on 21 June (the last chick likely hatched two days later on 23 June). The first fledglings (n=2) departed nest #5 on 3 July (both were seen in the nest on 2 July) and the last heron chick fledged between 13-15 August. No second nest attempts were observed. Chicks and adults did not remain in the Slate River wetlands post-fledging; most of the 117 herons departed by mid-August and either dispersed to local water bodies or further away, but we do not know the location of the herons from the Slate River colony after leaving the nests.		

The heron colony was divided into two sub-colonies. The lower colony consisted of 14 nests (all active) and the upper colony had 12 nests (11 active). Of the total 26 nests, 25 were active in 2018 (Table 3).

We do not have data on nest initiation dates, but at least 23 active nests were occupied by 19 May (Figure 4). All 25 active nests were occupied until 3 July. By 12 July, 24 nests remained occupied. On 16 July, only nine nests were occupied and this dropped to seven nests on 25 July. The number of occupied nests was down to four on 31 July, and only one nest remained occupied after 2 August with two chicks. One fledged on 12 August and the last chick fledged after 13 August, probably on 15 August.

Table 3. Great Blue Heron nesting phenology at the Slate River rookery in Crested Butte, Colorado. Data are from 2018 breeding season. Hatch dates represent the date the first chick was observed in the nest. One fledge date indicates all chicks had fledged, multiple fledge dates indicate range of fledge dates within a nest (chicks first observed in nest 21 on 19 June, but were older; estimated hatch date 9 June).

Colony Location	Nest Number	Number of Chicks	Hatch Dates	Number of Fledged Chicks	Fledge Dates
Lower Colony	1	2	9 May	2	9 July
	2	5	15 May	5	11 July (4), 16 July (1)
	3	4	1 June	4	23 July (3), 24 July (1)
	4	2	7 June	2	24 July (1), 30 July (1)
	5	2	17 May	2	3 July
	6	1	13 June	1	2 August
	7	2	29 May	2	7 July
	8	4	18 May	4	11 July
	9	3	21 May	3	11 July (2), 16 July (1)
	10	3	29 May	3	16 July
	11	3	29 May	3	9 July, 11 July (2)
	12	2	21 June	2	12 August (1), 15 August (1)
	13	4	18 May	4	16 July (3), 18 July (1)
	14	2	19 May	2	6 July
Upper Colony	15	4	17 May	4	9 July
	16	2	22 May	2	23 July (1), 30 July (1)
	17	1	3 June	1	13 July
	18	2	13 June	2	16 July (1), 26 July
	19	5	9 May	5	9 July
	20	4	18 May	4	9 July (2), 16 July (2)
	21	2	9 June*	2	19 July (2)
	22	1	30 May	1	11 July
	23	Unoccupied	NA	Unoccupied	NA
	24	3	25 May	3	16 July (1), 19 July (1), 23 July (1)
	25	2	7 June	2	30 July (1), 1 August (1)
	26	2	22 May	2	18 July (2)
	25 active	**67**	**9 May – 21 June**	**67 100% of chicks**	**3 July to 15 August**

We assumed the 25 active nests each had a unique adult pair, for a total breeding population of 50 adult herons. We did not observe unpaired, non-breeding adult herons. All 25 active nests produced at least one young (100% nest success). We do not know the number of eggs (clutch size) as we were only able to observe the number of chicks (brood size) in the nest. It is possible, that clutch sizes were different from brood size as a result of eggs that did not hatch (hatch success). The colony yielded 67 young with brood sizes varying from 1-5 and the average brood size was 2.7 ($\pm$1.2 std deviation, n=25). Two nesting pairs had a brood size of five chicks, five nests had four chicks, four nests had three chicks, 11 nests had

two chicks, and three nests had one chick (Figure 5). The estimated nestling period ranged from 39 days to 69 days with an average of 52.3 days (± 8.1 days standard deviation). Five-chick broods had a mean nestling period of 61.5 days (n = 2), four-chick broods averaged 56.2 days (n = 5), three-chick broods took 51.5 days (n = 4) to fledge, two-chick broods took 51.4 days (n = 11), and one-chick broods required 44 days (n = 3) to fledge (Figure 6). All 67 young appeared to have survived and fledged (100% fledgling success) and every nest had at least one fledging event (100% fledging success; Table 3).

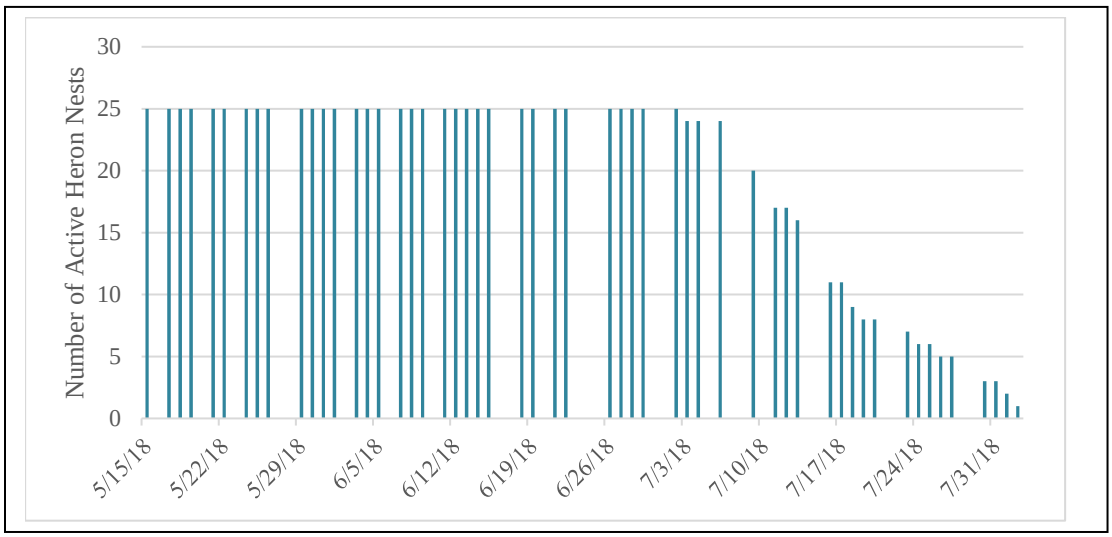


Figure 4. Number of active Great Blue Heron nests relative to time of year at the Slate River rookery in summer 2018.

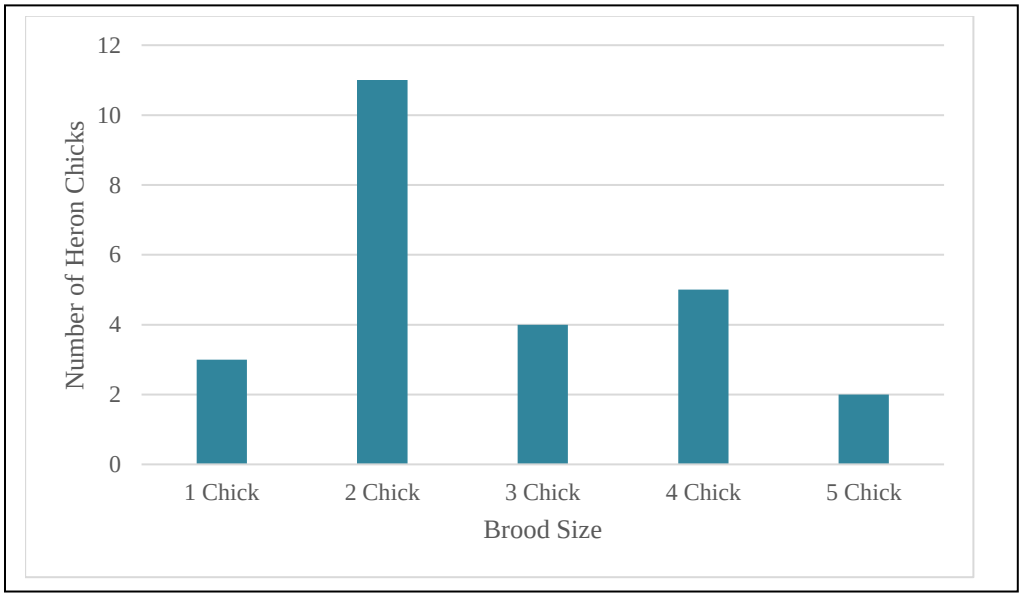


Figure 5. The number of Great Blue Heron nests relative to brood size (number of chicks in the nest) at the Slate River heronry in 2018.

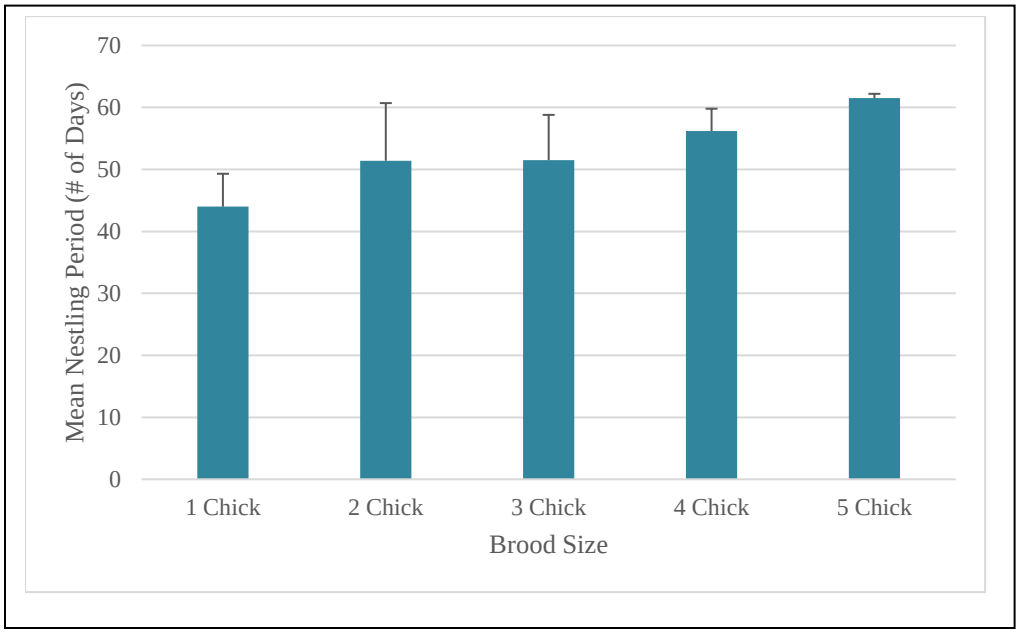


Figure 6. The mean length of the nestling period relative to brood size for Great Blue Herons at the Slate River heronry in 2018. Standard deviation bars indicate variability in nestling period.

Great Blue Heron behavior within the colony

Scan Sampling

We conducted 115 scan samples of the heronry. On 29 occasions, no herons were present and all but one of these occurred on or after 16 July when many of the nestlings had fledged. Of the remaining 86 scan surveys, 34 were done in the morning, 28 during the day, and 24 in the evening. The number of herons present in the colony did not differ significantly by time of day ($p = 0.13$, $F = 2.08$, $N = 103$) (Figure 7).

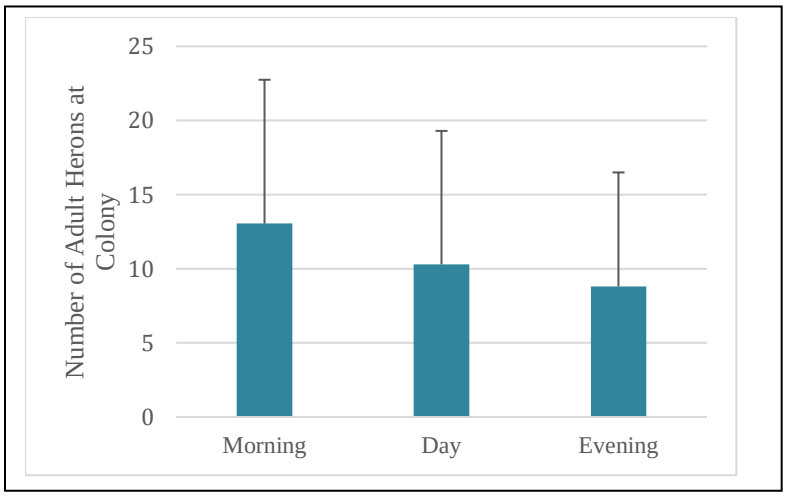


Figure 7. Number of adult herons present at the nesting colony relative to the time of day. Data from the Slate River heronry in summer 2018.

Of the 35 possible behaviors grouped into eight categories, we observed 14 behaviors in seven of the categories using scan sampling at the nests. Great Blue Herons spent 99% of their time in three primary activities during the breeding season from mid-May until the end of July 2018. Across this time frame, adult herons spent 41% of their time brooding young, 30% conducting self-maintenance behaviors (primarily preening and stretching), and 28% of their time incubating eggs (Figure 8). Herons spent less than 1% of their time being vigilant (0.31%), courting (0.23%), flying to or from the nest (0.21%), and feeding at the nest (0.17%). During 10 of 86 surveys, all herons were synchronized in the same behavior.

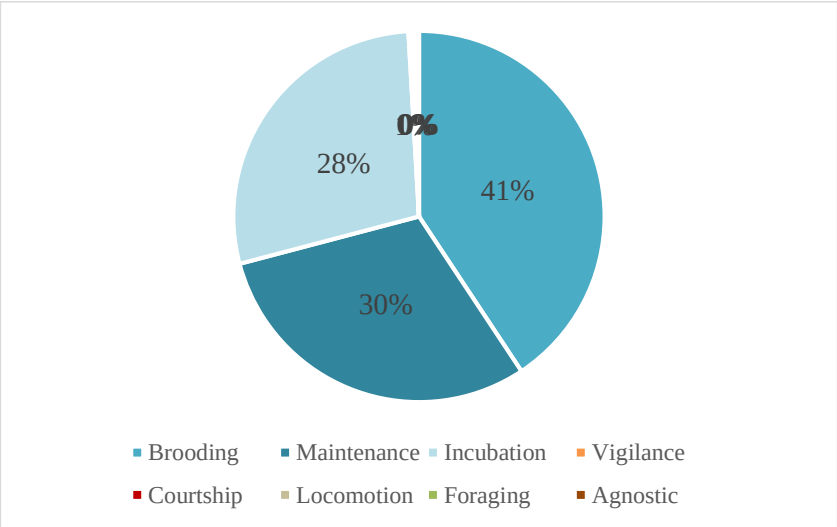


Figure 8. Great Blue Heron activity budget based on scan samples of adult herons in their nests from mid-May to the end of July 2018 at the Slate River heronry. Photo by Carley Clegg.

Heron behavior did not differ significantly among times of day for the three primary activities (Table 4). Brooding behavior significantly increased from 37.6% of their time before 23 June to 56.0% of their time after 3 July ($p = 0.01$, $t = -2.4$, $N = 74$) (the last chick hatched on 23 June ending the egg stage).

Table 4. Great Blue Heron time budget from scan sampling in relation to time of day. Data are percent time spent in behaviors and were collected at the Slate River rookery in Crested Butte, CO from mid-May to late July 2018.

Behavior	**Morning**	**Day**	**Evening**	**ANOVA p-value**
Foraging	0.4	0	0	NA
Locomotion	0.2	0	0.5	NA
Self-maintenance	27.8	34.0	29.8	0.62
Courtship/mating	0.5	0	0.2	NA
Vigilance	0.2	0.7	0	NA
Incubation	31.5	26.7	25.6	0.49
Brooding	39.2	40.5	43.9	0.78
Agnostic	0	0	0	NA
Total	99.8	100.9	100.0	
Sample Size	35	29	25	

Focal Sampling

We conducted 601 focal time budget samples on individual herons, or 21,020 minutes of observation (200 hours). Of these focal time budgets, 277 were conducted when no heron occupied the nest to provide data on nest occupancy rates. The 324 remaining surveys were divided into adults (N = 259) and juveniles (N = 65), and herons in nests (N = 306) and in the adjacent wetlands (N = 12).

Overall, from 15 May to 12 August, 94% of our observations were of Great Blue Herons within their nests. They spent the largest proportion of their time in self-maintenance behaviors (37.3%), especially preening and stretching (17.8%) and roosting in a standing position in the nest (10.6%). Brooding behavior (primarily attending to chicks) occupied 30.5% of their time and herons spent 21.4% of their time incubating eggs. They spent 4.6% of their time foraging. Herons spent 2.6% of their time in locomotion (mostly in flight from foraging areas outside the immediate colony and adjacent wetlands and in flights from the wetlands to the nest). They were vigilant for 3.1% of their time budget and courtship and agnostic behaviors accounted for less than 1% of their behaviors at the nests (Figure 9).

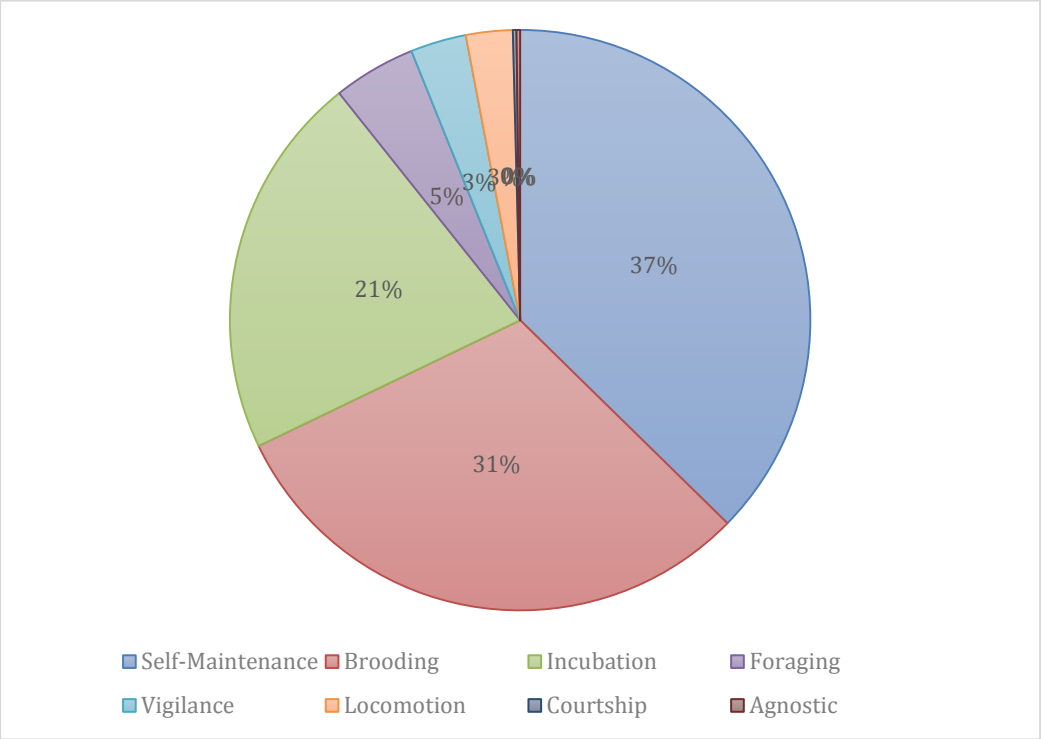


Figure 9. Focal time budget of Great Blue Herons at the Slate River colony from 15 May to 12 August 2018.

Focal activity budgets of adult and juvenile Great Blue Herons

Adult herons spent most of their time incubating eggs and brooding young, in contrast to juveniles. Juveniles spent 86.5% of their time in self-maintenance behaviors and 9.2% of their time being vigilant in the nest (Table 5). Juvenile vigilance was significantly greater than adult vigilance.

Table 5. Adult and juvenile Great Blue Heron focal time budgets (% time spent in activities) at the Slate River heronry in Crested Butte, CO in summer 2018. Total observations of adult birds was 259 compared to 65 juveniles.

Behavior	Adult	Juvenile	p-value	t-stat	Sample Size N
Foraging	5.09	2.81	0.16	1.39	324
Locomotion	3.18	0.57	<0.0001	4.62	324
Self-maintenance	24.94	86.51	<0.0001	-19.9	324
Courtship	0.23	0.04	0.002	2.82	324
Agnostic	0.02	0.88	<0.0001	-5.2	324
Vigilance	1.6	9.2	<0.0001	-5.3	324
Incubation	26.8	0	NA		
Brooding	38.1	0	NA		
Total (% time spent in behaviors)	99.96	100.01			

Photo by Carley Clegg

Great Blue Heron focal activity budgets in nests versus wetlands

Incubation and brooding by adults were activities not applicable outside the nest. No courtship or agnostic behaviors were observed by herons in the wetlands. The primary activity in the wetlands was foraging, accounting for 62% of the adult time budget compared to 1.4% in the nest (Table 6). Patient herons in the Slate River wetlands primarily foraged using the standing-in-wait method characterized by prolonged bouts of standing still, in silence, ankle-deep, peering into the water for prey.

Table 6. Focal time budgets of Great Blue Heron adults (percent time spent in behaviors) in wetlands and in nests at the Slate River heronry. For wetland herons the sample size was 12, whereas the sample size for nesting adults was 243. Courtship, agnostic behavior, incubation, and brooding behavior were not observed in the wetlands, and no statistical comparison was made.

Behavior	Wetlands	Nesting Colony	p-value	t-stat	Sample Size N
Foraging	61.99	1.38	<0.0001	7.30	255
Locomotion	8.59	2.76	0.09	1.85	255
Self-maintenance	26.29	25.10	0.45	0.12	255
Courtship	0	0.25			255
Agnostic	0	0.02			255
Vigilance	3.12	1.56	0.36	0.66	255
Incubation	0	28.55			255
Brooding	0	40.38			255
Total	99.99	99.97			

Seasonal differences in Great Blue Heron behaviors

Adult heron behaviors were compared during the egg stage (incubation) to the nestling stage (brood rearing). These comparisons are more seasonal in nature than specific to the life cycle event, as breeding stages were not synchronized among the heron nests and are not easily defined by calendar dates. The nestling stage was defined as the period after the last chick hatched and the first chick fledged (3 July and after). The egg stage was defined as the period up to the last hatched nest (23 June). Brooding behavior was the dominant activity during the nestling stage and was significantly greater than during the incubation stage (Table 7). Flights in and out of the nest were significantly more frequent in the nestling stage and foraging tended to be higher but the difference was not significant. Self-maintenance was significantly greater in the incubation period and dropped from 26% of the adult's activity budget to 9.5% during nestling (Table 7). Foraging and locomotion accounted for just 4% of the behaviors of adults prior to 23 June, compared to over 25% in July. This, along with the time allotted to self-maintenance, incubation and brooding (94% of time budget), reflects the strong association of adults to the nest throughout May and June. During July self-maintenance and brooding dropped to 69%.

Table 7. Adult Great Blue Heron focal time budgets (percent time spent in behaviors) in incubation stage (prior to 23 June) and nestling stage (3 July and after) at the Slate River heronry in Crested Butte, CO in 2018. Total observations of adults during incubation was 209 compared to 20 during fledgling.

Behavior	Incubation	Nestling	p-value	t-stat	Sample Size
Foraging	2.83	9.98	0.10	1.71	229
Locomotion	1.48	14.53	0.0002	4.27	229
Self-maintenance	26.50	9.49	0.002	-3.42	229
Courtship	0.27	0			229
Agnostic	0	0.02			229
Vigilance	1.35	6.44	0.28	1.10	229
Incubation	31.71	0			229
Brooding	35.83	59.55	0.001	3.44	229
Total	99.97	100.01			

Great Blue Heron behavior relative to time of day

Adult Great Blue Herons fed less in the morning and no other behaviors differed by time of day (Table 8). Courtship and vigilance, as well as incubation and brooding behaviors tended to be higher in the morning, but none of these comparisons was significant statistically.

Table 8. Adult Great Blue Heron focal time budgets (percent time spent in behaviors) comparing behaviors by time of day at the Slate River heronry in Crested Butte, CO during 2018. Total observations of adults was 259 with 107 morning observations, 81 daytime observations, and 71 evening observations.

Behavior	Morning	Day	Evening	p-value	F-stat	Sample Size
Foraging	1.85	8.28	6.32	0.03	3.46	259
Locomotion	2.73	3.47	3.53	0.76	0.23	259
Self-maintenance	23.41	23.5	28.9	0.38	0.97	259
Courtship	0.37	0.15	0.11	0.11	2.22	259
Agnostic	0.05	0	0	0.24	1.43	259
Vigilance	1.85	1.66	1.18	0.90	0.09	259
Incubation	28.43	26.14	25.03	0.85	0.16	259
Brooding	41.30	36.79	34.93	0.45	0.79	259
Total	99.99	99.99	100.00			

Great Blue Heron nest occupancy

Great Blue Heron nest occupancy was measured with focal time budget data. Percent time that heron nests were vacant was recorded. Prior to 25 May, random samples did not include any vacant nests suggesting that from spring arrival and nest building, nests were occupied nearly continuously (however more detailed time budget studies are needed for the early period). About three weeks after the first chick hatched (7 May, Table 2) we observed vacant nests and by 5 June (one month after the first chick hatched), we recorded extended absences at the nests. From 5 June to 5 July nest attendance varied depending on the stage of nesting for each nest. After 5 July, nest vacancy increased and 60-100% of the time we observed nests, they were unoccupied by adults (Figure 10).

Herons were present in their nests more in the morning than during day or evening periods ($p = 0.02$, $F = 3.76$, $N = 520$). Herons were absent 52.7% of the time in the morning compared to 60.5% in the day and 66.6% in the evening (Figure 11).

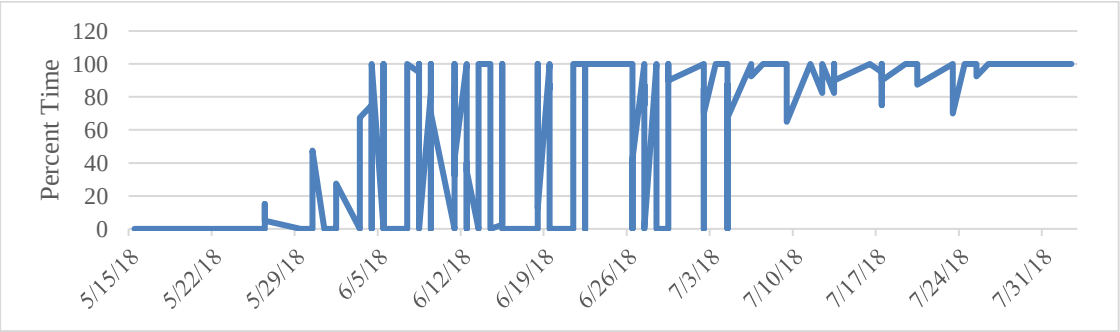


Figure 10. Relationship between percent time herons did not occupy their nests during focal time budget sampling and date of observation at the Slate River heronry from 15 May to 2 August 2018.

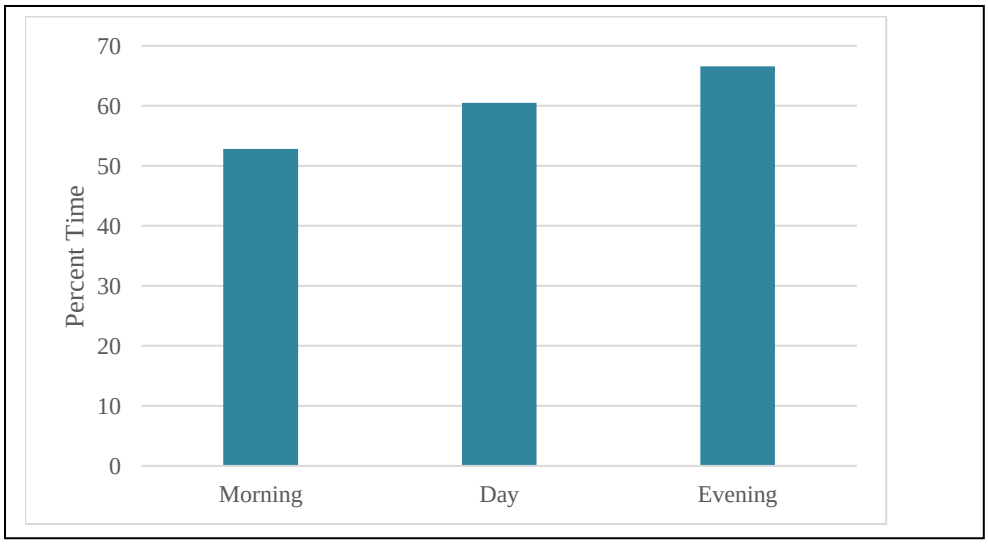


Figure 11. Percent time herons were not present in nests during focal time budget sampling relative to the time of day. Nest occupancy was significantly different among the time periods. Data collected at the Slate River heronry in summer 2018.

Human activities and potential disturbances to the Great Blue Heron colony

General Disturbances

On 34 days we conducted 59 1-hour observation bouts to sample potential disturbances around the heron colony from 26 May to 1 August 2018. Data were collected between 053-1900. We recorded 3,520 human activities on the Slate River Road, trails, the sky above, and the Slate River (Table 9). Of these, 93 included loud noises (2.6%). Overall herons responded in three ways: no noticeable behavior change (91.5%), change to alert behavior in the nest (7.4%), or flush (fly from the nest, 1.1%). Of the 3,520 events, 301 (8.5%) led to possible disturbance responses by the herons. Chick alert behavior was observed during 233 (6.6%) of these events, adult alert behavior was observed 29 times (0.8%), and adult flushes were recorded 39 times (1.1%). Over 91% of documented human activities did not elicit a heron disturbance behavior.

Table 9. Human activities adjacent to the Slate River Great Blue Heron colony and potential disturbance related to eight types of human events. Data collected from 26 May to 1 August 2018 in 59 1-hr sampling bouts. Total number of people was not observed for cars and trucks, so this is a conservative number.

Human Activity	Number of Events	Percent of Total Events	Number of Noise Events	Number of People	Adult Heron Alerts	Chick Heron Alerts	Adult Heron Flushes
Cars and trucks	2,719	77.0%	36	na	8	157	1
Total bikes	447	12.7%	2	896	2	7	0
Smith Hill bikes	*276*	*7.8%*	*0*	*586*	*0*	*2*	*0*
Slate River Road bikes	*167*	*4.7%*	*2*	*296*	*2*	*4*	*0*
Wildbird bikes	*4*	*0.1%*	*0*	*14*	*0*	*1*	*0*
Planes and helicopters	229	6.5%	4	na	0	28	0
Runners and hikers	51	1.4%	4	169	0	5	1
Dirt bikes, motorcycles, 4-wheelers	45	1.3%	36	42	0	17	0
Radios and alarms	7	0.2%	7	na	0	7	0
Livestock	2	<0.1%	1	4	0	1	0
River recreation	20	0.6%	3	76	19	11	37
Total	**3,520**	**100%**	**93**	**1187**	**29**	**233**	**39**

Based on the 59 disturbance sampling bouts, the mean number of human activities per hour at the Slate River colony was 59.9. This included 46.3 cars/trucks per hour, 7.7 bikes per hour, 5.0 planes per hour, 0.8 hikers/runners per hour, and 0.8 dirt bikes/motorcycles/4-wheelers per hour. Watercraft accounted for 0.12 events per hour. Other activities accounted for less than 0.1 event per hour. The lowest number of human activities was 8 per hour and the high was 130 per hour.

Human activity around the heronry changed seasonally (Table 10). The number of human events per hour peaked at 85 in the first week of July 2018. The lowest activity occurred in the last week of May with 21 human events per hour. Activity also varied by time of day with the fewest human activities in the morning (mean of 37 events per hour from 550-955) compared to the peak in the middle of the day (79 events per hour from 1015–1445) and this trailed off in the late afternoon and evening (60 events per hour from 1515-1850; Table 11).

Table 10. Number of human events per hour in relation to week during the Great Blue Heron nesting season at the Slate River heronry in Crested Butte, CO during summer 2018. The data are the mean number of events per hour. Air traffic was not documented until 14 June.

Week	Total	Cars/ trucks	Bikes	Dirt bikes	Hikers and runners	Air traffic	River floaters
26-31 May	21	14.7	12.7	0.5	0	na	0
1-8 June	33	27.2	4.3	0.2	0.8	na	0.2
9-16 June	44	33.5	6.4	0.2	0.4	2.5	0.5
17-24 June	79	56.6	16.0	0.8	1.6	4.0	0.4
25-30 June	81	63.1	10.6	0.6	0.6	5.4	0
1-8 July	85	72.3	7.2	1.0	1.7	2.5	0
9-16 July	83	62.3	11.5	0.3	0.8	7.8	0
17-24 July	60	44.5	7.2	2.2	0.7	5.2	0
25 July – 1 August	45	35.2	2.8	0.2	1.0	5.9	0

River Recreation

From 26 May to 25 June we recorded 20 events (groups of floaters) on 9 days where watercraft floated down the Slate River underneath the Great Blue Heron colony. No river recreation was observed after 25 June 2018 during our observations. The 20 potential disturbance events consisted of 34 SUP boards, 16 kayaks, 4 duckies, a raft, and 4 unknown watercraft (couldn't be seen from Slate River Road observation point). A minimum of 76 people floated the colony stretch, with groups of more than 10 people on three occasions, and during one event some of the 17 recreationists in 16 crafts walked through the creek under the colony. At least three events included loud noise – audible from 300 m or more. These disturbances led to 19 adult herons and 11 chicks changing their behavior to alert posture in the nest and 37 heron flushes (flew out of the nest). The average time herons were away from their nests after flushing was 4 minutes for 9 events where time was documented. Watercraft events accounted for 95% of all heron flushes recorded for all types of human activity monitored. Only two non-river events caused herons to flush – one was a loud vehicle on the Slate River Road and the other was a hiker walking along the Wildbird ridge at a distance of 180 m from the colony. River recreation was also associated with 65% of adult alert behaviors and 5% of juvenile alert behaviors.

Table 11. Number of human events per hour relative to time of day during the nesting season at the Slate River heronry in Crested Butte, CO during summer 2018. Data are mean number of events per hour.

Time of Day	Total	Cars/ trucks	Bikes	Dirt bikes	Hikers and runners	Air traffic	River floaters
Morning	37	28.9	2.3	0.3	0.8	4.5	0
Day	79	59.7	13.2	0.6	1.1	3.7	0.1
Evening	60	47.9	6.6	1.3	0.7	3.5	0.2

DISCUSSION

Baseline phenology and nesting demography

Our study provides the first known baseline demographic data and phenological description of the Great Blue Heron colony in the Slate River wetlands (Figure 12). However, these data are incomplete and include important gaps in the early stages of the breeding season and in overall detail. The herons arrived surprisingly early, before the middle of March, when the breeding grounds were encased in snow and ice. The 2018 winter was quite mild, so it is unclear whether the early arrival was related to the comfortable weather or whether the herons arrive at a similar time every year. In the case of a more normal winter (snowfall and temperature) it is likely the Slate River wetlands retain deep snow for at least a couple more weeks. This early arrival when foraging opportunities are restricted suggests the heron feeding habitat may be geographically decoupled from the rookery site. Great Blue Herons often nest in distinct habitats more than 5 km from foraging areas and may fly 30-40 km to foraging sites (Knight 2010, Custer et al. 2004) that are buffered from human activity (Parker 1980). During the egg and nest stages in our study, few adult herons were observed foraging in nearby wetlands or in the Slate River – the majority moved at least out of visual range of the colony. Both adults and juveniles apparently departed the Slate River wetlands almost immediately after chick fledging rather than using aquatic habitats adjacent to the rookery for foraging or returning to the nests, which is common in other breeding populations (Vennesland and Butler 2011). These patterns may be related to quality and/or quantity of foraging habitat, the solitary/territorial nature of herons when feeding, and the possible risk aversion threshold associated with high human activity in the Slate River valley which peaks in early to mid-July. In our relatively few observations of herons using wetlands below the nests, they spent 61% of their time foraging. We documented a local colony population of 50 adults and 67 juvenile Great Blue Herons. This high number of predators require sufficient space to pursue their prey using a standing-in-wait method that requires long, uninterrupted foraging bouts. Herons must spread out across the landscape, especially in a high elevation montane system where secondary productivity is constrained by low nutrient, cold water (Vannote et al. 1980). The low productivity stream and wetlands coupled with the need for a high calorie diet as well as high demands for provisioning food for up to five chicks, possibly pushes herons to a physiological edge. With the high rate of human activity in the Slate River valley and the potential for disturbance, herons may depart the valley as soon as the chicks attain flight in search of other foraging opportunities.

We documented 25 active nests in the Slate River colony. In Colorado, heronries with more than 20 nests are considered large colonies (Brown and Dexter 2016), however, other Great Blue Heron rookeries may contain 500-1,000 nests (Witt 2006). In the Great Plains region, including Colorado, median colony size is around 10 nests (Nancy Drilling, Bird Conservancy of the Rockies, personal communication). Larger colonies tend to have longer persistence (Kelly et al. 2007) and higher productivity (Vennesland and Butler 2011). We were unable to document clutch sizes but every active nest was successful (produced at least one chick). Great Blue Herons lay clutches of 2-6 eggs (Vennesland and Butler 2011) and produce 1.5-3.3 fledglings per successful nest (Vennesland and Bulter 2011). Brood sizes for the Slate River heronry ranged from 1-5 with a mean of 2.7 chicks per nest and 2.7 fledglings per successful nest. We did not observe nestling mortality and every nest appeared to have successfully fledged at least one chick. We observed red-tailed hawks and osprey in the wetlands but no depredations were observed. We did not

Table 12. Phenology of life cycle of Great Blue Herons at the Slate River rookery compared to studies conducted elsewhere in North America. Phenological data for herons from the Birds of North America account (Vennesland and Butler 2011) and otherwise more specific citations are provided.

Life cycle event	Slate River Heronry 2018	Birds of North America (Vennesland and Butler 2011)
Spring migration, Arrival	13 March	Varies from early February to early May across North America
Gathering Grounds	Not observed	In some locations herons gather in flocks before entering colony site
Pair formation	No data	Late March in Alberta (Vermeer 1969) and British Columbia (Butler et al. 1986)
Nest building	13 March – ?, No data	3 day to 2 weeks
Egg laying	9 April – 21 May (6 weeks)	3rd week of March in Idaho (Collazo 1981) Late April in Alberta (Vermeer 1969)
Incubation Egg Stage	9 April – 23 June (10 weeks)	Males and females incubate for 27-29 days; Males incubate for 10 hr/day, females incubate for 3.5 hr/day and at night (Brandman 1976) Adults incubate for 54 min/hr (Pratt 1970)
Hatching	7 May – 23 June (7 weeks)	Eggs hatch 1.5-2.0 days apart (Mock 1978) or on same day (Pratt 1970)
Brooding Nestling Stage	7 May – 15 August (15 weeks)	Begins immediately after hatching and lasts 3-4 weeks. Peak provisioning occurs at 29 days and chicks fed regurgitated food until day 30. Two day old chicks fed 10 times in 13 hours and 65 day old chicks fed twice in 15 hours (Pratt 1970).
Fledging	3 July – 15 August (7 weeks)	Occurs 7-8 weeks post hatch (Werschkul et al. 1977, Quinney and Smith 1979). First flight at 52 days in Alberta (Vermeer 1969), 81 days in California.
Fledgling Stage	Fledglings largely disappeared immediately after fledging	Fledglings may return to nest for up to 3 weeks post-fledge and be fed by adults (Quinney and Smith 1979) or return by themselves (Butler 1997).
Second Broods	None observed	Occurs in locations with mild climate for long nesting period. Some herons choose a new mate especially if first brood failed.
Fall migration Departure	Adults and fledglings departed the Slate River wetlands soon after fledging. We do not have data on their locations.	Mid-September to late-October, November in Alberta and December in Ontario.

observe brood size reduction in any nest up to fledge time. It is possible that some chicks perished near fledging time and we interpreted that as a successful fledge event (chick no longer in the nest), however,

we witnessed many chicks flying off the nests and most nests emptied in a short period of time indicating successful fledging. Our results suggest 100% fledgling success.

Further documentation of spring arrival and more detailed observations of colony size in the first few weeks after the first bird arrives would provide a better understanding of the early phase of the breeding season. We only made casual observations from 14 March to 15 May in 2018 and did not provide detailed information on spring arrival, nest site selection, nest building, courtship, pairing, mating, or nest initiation. In future studies more detailed accounting of individual nests would provide better estimates of incubation and nestling periods. Accurate identification of nests was complicated by obstructed views through dense vegetation and as a result of varying perspectives from different observation points. The Wildbird ridge observation point provided the closest range and excellent viewing through a spotting scope, however, not all nests could be observed clearly. A few nests were much better observed from the east side of the colony from the Slate River Road observation point. Multiple perspectives are required to obtain accurate counts and observations of heron behaviors.

Time Activity Budgets

Evolution produces optimal allocation of time and energy (Altmann 1974). Our study documented adult heron activities from late May to early August within nests and on adjacent wetlands, although our sample sizes are small in wetlands. We quantified nest behavior of adults using two methods and both showed that feather care, incubation and brooding behaviors accounted for most of the time at the nest. Importantly, amount of time spent in a behavior is not necessarily related to the importance of the activity. For example, adult herons spent 1.6% of their time in the nests in alert behavior. While this is a small expenditure of time, it may be one of the most important behaviors related to survival. Further, foraging time was minimal for adults in the nest and we only observed feeding when an adult brought food to the nest. In contrast, we documented off-nest behavior of a few herons and these data suggest that adults spent almost two thirds of their time (62%) foraging while away from the nest. A more detailed 24-hour time budget on and off the nest would require the ability to identify males from females and document which adult attended the nest for how much time. Previous research suggests that males spend about 10 hours per day on the nest during incubation, while females incubate the eggs for the rest of the day and most of the night (Brandman 1976). Although we did not discern heron gender, nest attendance was higher in May and early June and was also higher in the morning than during the day or evening. These times may represent periods of higher vulnerability.

Human Disturbance

Human activities lead to disruption of Great Blue Heron breeding events when proximity of human activity is close to the rookery and when the timing of human activities overlap with critical heron life cycle events. Numerous studies have documented negative impacts of human activities on Great Blue Heron nesting (Parker 1980, Vos et al. 1985, Butler 1992, Hockin et al. 1992, Parnell et al. 1988, Corley-Martinez 1995, Vennesland 2000, Machmer and Steeger 2004, Vennesland and Bulter 2004, Vennesland 2010). Few studies suggest habituation of herons to human activities (Vennesland 2000). Most of the human activity that we observed in the Slate River valley had relatively benign effects on the colony. We recorded 3,520 human activities in the vicinity of the rookery and less than 1% were river recreationists. However, 95% of heron flushing events were attributed to river recreation. Cars and trucks represented 77% and bikes 13% of these activities, most of which took place on the Slate River Road or the Smith

Hill Road (for bikes). The nearest distance the Slate River Road comes to the colony is about 240 m. Traffic on the road only comes that close to the heronry for a short segment and most human activity is much greater than 300 m from the colony. These distances provide an adequate buffer to human activities (Buckley and Buckley 1978, Parker 1980, Bowman and Siderius 1984, Vos 1985, Vennesland and Butler 2004). At the Slate River heronry, river recreation occurs immediately below the heron nests providing no horizontal spatial buffer. Heron nests on the Slate River are positioned in the crowns of spruce trees that line the banks of the river. Like other heronries, the nests are approximately 30 m above the river channel (Vennesland and Butler 2011). The width of a buffer and its effectiveness in separating human activity from heron nests has been correlated with higher heron reproductive success (Carlson and McLean 1996) and researchers typically recommend 250-300 m buffers for effective separation (Parker 1980, Taylor et al. 1981, Vos et al. 1985, Quinn and Milner 1999, Machmer and Steeger 2004, Vennesland and Butler 2004). In one study, mean distance from disturbances to active nests was 220 m compared to 150 m to inactive nests (Werschkul et al. 1977). Our data suggest that river recreation, including SUP boards, kayaks, duckies and rafts, whether in small or large groups that are quiet or loud, result in disturbance behavior more than 9 out of 10 times. On average, each river disturbance results in 1.85 herons flushing from their nests.

Numerous studies indicate that colonial nesting Great Blue Herons are especially vulnerable to human disturbance early in the nesting season (Vos et al. 1985, Butler 1995, Vennesland 2010). Herons are more likely to abandon colony sites during pair formation, nest building and egg laying (Machmer and Steeger 2004). Probability of nest abandonment declines after hatching (Vos et al. 1985, Parnell 1988, Vennesland 2010). In our study, the last heron chick hatched on 23 June. We did not observe any river recreation after 25 June in 2018, and could not assess disturbance to the Slate River colony during this late stage. River flows were extremely low (89 cfs on 20 June) from mid-June to August and already below the threshold for ethical floating. In years with higher run-off and longer floating seasons it is likely that river flows could support watercraft into July.

With substantial investment in the nesting effort, adult herons flush less frequently during late incubation and throughout the nestling stage (Vennesland 2000). Fewer disturbances to nests in late season have been linked to heavier foliage that obstructs the view of human activities (Taylor et al. 1981); this is not an issue at the Slate River heronry where nests are in evergreen trees and foliage doesn't change much seasonally. Less frequent flushing is not necessarily a reflection of lower disturbance, as adults may alter behavior patterns leading to less efficient brooding and foraging and they may experience stress that could lead to lower fitness. At this time adults ramp up their foraging effort to provision young and face their highest daily energy demands during the early chick stage (require 4,264 ± 764 KJ/day; Butler 1991). Adult herons foraging in the Slate River and in adjacent beaver ponds and oxbow ponds could be displaced by floaters leading to a loss of foraging time and efficiency, and negative fitness consequences, especially to the young waiting for a meal (Machmer and Steeger 2004). Nestling herons remain vulnerable throughout the nest stage until they fledge. Immature chicks when disturbed may be more vulnerable to predation if adults leave the nest and juveniles may leave the nest resulting in injury or death (Parnell et al. 1988).

Our sampling was not sufficient to quantify river recreation throughout the 2018 season and does not reflect the amount of river use that is likely during wetter years when flows are higher for longer duration.

We estimated an average rate of 60 human events per hour in the lower Slate River valley during the nesting period. Over a 12-hour day (from 600-1800) the total number of events is roughly 720 per day. During the 66 day period from 26 May to 1 August (the duration of our disturbance sampling), 47,520 events occur in the valley (36,696 are vehicles or 556 vehicles per day). These are rough estimates and actual numbers vary seasonally and with time of day, and depend on more thorough sampling. We recorded 0.12 rivercraft flowing underneath the heronry per hour during our 59 formal disturbance monitoring surveys. This only accounts for 7 of the 20 floating events we observed during the study. We started our disturbance monitoring on 26 May (late in the season) and it is likely that recreationists floated prior to the start of our sampling. We witnessed watercraft near the heronry until 25 June. The low run-off made 2018 an extreme year for river flows and greatly narrowed the window for floating. A rate of 0.21 rivercraft per hour, equates to 1.4 floater events per day or 43 per month. The average number of heron flushes per floater event was 1.85 which would result in 2.7 flushes in the colony per day or 79.6 per month. Actual participation was at least 4-5 times what we recorded (7 events out of 3,520 give the rate of 0.12 events per hour vs. 20 events out of 3,520 gives 0.57 events per hour) and at the rate of 0.57 events per hour the colony would experience 8 flush events per day and 239 per month. Both rough estimates of river recreation on the lower Slate provided here are conservative. And Great Blue Herons likely experience higher rates of watercraft disturbance.

"…the fortunes of Great Blue Herons are inexorably linked to human activities."
Alexander Brown and Coen Dexter 2016

MANAGEMENT IMPLICATIONS

The Great Blue Heron rookery on the Slate River represents a unique eco-geographical convergence. There is a limit to the number of appropriate heronry locations across a landscape. Herons choose colony sites based on energetic profitability related to local food supply (Gibbs 1991) and relative isolation from human disturbances (Watts and Bradshaw 1994). The Slate River colony is special because of its large size (>20 nests), its location in a high elevation montane riparian ecosystem, its presence in coniferous treetops (only 5% of Colorado's colonies; Brown and Dexter 2016), and its apparent longevity and high productivity. Great Blue Heron rookeries historically have occurred at over 8,000 feet in Colorado's mountain parks (Cooke 1900, Sclater 1912), but colonies near 9,000 feet are not documented. The Slate River colony is at 8,900 feet. It is unclear how long the heronry has existed and informal interviews with locals have produced inconsistencies in oral memories. There is no mention of the heronry in Cooper's 1993 wetland report. Denis Hall took photos of the herons in 2003 at the current location. It is likely that the colony has been in its current location for at least 20 years. Significant tree mortality indicates relatively long residence time as heron occupancy of crown nests leads to tree mortality due to fecal droppings (Brown and Dexter 2016). As more of the trees die and fall, the heronry faces an uncertain future, and depends on the number of persistent crowns.

Many of Colorado's Great Blue Heron colonies are highly transient with new colonies being established and old ones being abandoned every year (Miller and Graul 1987, Levad and Leukering 2002). Individual colonies can also experience large fluctuations from year to year (Levad and Leukering 2002).

The Slate River colony is a long-lived, large colony which potentially contributes significantly to landscape scale population stability. Larger colonies tend to have higher productivity and perseverance (Vennesland and Butler 2011). We only have a single year of demographic data on the Slate River colony, so we lack understanding of the variation experienced among years and factors correlated with annual population changes. We also lack knowledge of a population trend for this colony. Annual monitoring of the Slate River colony and other sites in the Gunnison Basin would provide a better understanding of local temporal dynamics, population movements, and colony stability. The Bird Conservancy of the Rockies created Colony Watch, a volunteer-based monitoring effort for Colorado's colonial nesting waterbirds. As a way to contribute to the science and conservation of Great Blue Herons, the local Gunnison Basin community could participate in this program (http://rmbo.org/v3/avian/CitizenScience/ColonyWatch.aspx).

Photo by Denis Hall (Slate River heronry circa 2003)

Breeding populations of Great Blue Herons are sensitive to human disturbance and may respond with increased vigilance leading to greater stress and less time foraging, incubating or brooding young (Vennesland and Bulter 2011). Adults may spend less time at the nest leaving eggs and chicks more vulnerable to weather and predation, and consequently higher egg or chick mortality, reduced chick mass, and premature fledging resulting in lower survival of young (Rodgers and Smith 1995, Vennesland 2000) and lowered reproductive success or population declines (Skagen et al. 2001). Herons tend to have a low threshold for disturbance and ultimately may abandon colonies (Parker 1980, Vennesland 2000). They are especially vulnerable to nest abandonment as a result of pedestrian-based, recreational activities (Ryder et al. 1979, Watts and Bradshaw 1994, Levad and Leukering 2002). A Great Blue Heron colony

along the Gunnison River moved multiple times before 1980 as a result of human activities (Hyde 1979). The optimal situation for the Slate River herons is a disturbance-free environment during the breeding season to allow uninterrupted nesting activities and foraging in nearby wetlands.

In landscapes with significant human activity, spatial buffers have been useful to dampen disturbance effects. The Vermont Fish and Wildlife Department suggested restriction of all recreational activities within 200 m of rookeries (Vermont Fish and Wildlife Department 2002). In most scenarios recommended buffers range from 100-300 m. Great Blue Herons especially respond to disturbances at close range that are within their line of sight (Taylor et al. 1981). In shared human/heron landscapes, herons are able to habituate to peripheral human activities more than 500 m from colonies and where visual cues are reduced (Taylor et al. 1981, Corley-Martinez 1995, Parnell et al. 1988, Vennesland 2000), but they rarely habituate to disturbances that are closer to heronries. While the vast majority of human activities we observed in the Slate River valley were benign in impact to the heronry, they occurred at distances greater than 250-300 m from the nests. River recreation, on the other hand, lacked a spatial buffer and was associated with 95% of heron flush events. Because the Slate River heronry is located in a wetland, the marshy substrate restricts many forms of human visitation (hiking, running, biking). The main access through the valley bottom is via the river and the primary human activity at close range that we observed was river recreation. We did not observe anglers wading the stream or walking the banks, but similar to watercraft their presence would probably result in an equivalent level of disturbance to the herons. During the most vulnerable time for heron colony abandonment, from arrival to egg laying, the snow and ice-covered landscape potentially could be accessed by cross-country skiers. Skiers within 300 m of the colony during March and April would be highly visible on the snow surface and could cause significant disturbances during a critical period of the heron's annual cycle.

Without the option of applying spatial buffers, minimizing disturbance by river recreationists, anglers, skiers and other forms of up-close pedestrian human activities could be accomplished by temporally restricting river and wetland access. Temporal closures may prevent behavior changes in herons that lead to increased stress, lower productivity and reduced feeding efficiency or colony abandonment. Temporal closures should coincide with the timing of vulnerability. In other locations, temporal closures from 15 March to 1 August have been suggested (Vermont Fish and Wildlife Department 2002). Because herons put all their eggs in one nest location, have an extended breeding season (155 days in the Slate River wetlands), and are highly sensitive to human disturbance, conserving this species requires unique strategies. Minimizing human activities within 300 m of the colony from 15 March to 15 August would provide the most comprehensive protection. In 2018, only one nest was active after 2 August, so opening river access after 1 August would provide sufficient protection, but further monitoring in successive years will provide better information on nest completion dates.

RESEARCH NEEDS

Further research on the Slate River heronry is needed to better understand timing of breeding events, especially during the early period from spring arrival to egg laying. We scantily documented the window of heron arrivals in March, courtship, pairing, and nest building. Colony monitoring would need to start before 10 March. Additional data are needed to more fully assess heron demographic characteristics. Most importantly is annual monitoring to assess the long-term health of the colony in relation to land-use, climate change, stream flows, and other factors. Monitoring could be in collaboration with BCR's Colony Watch program.

The Slate River Working Group Management Plan calls for continued river recreation in 2019. Coordination of river recreationists and disturbance monitoring by researchers should occur in an experimental manner to assess effects of floater group size (number of craft and number of people), type of craft, and noise on heron behavior.

We have almost no information on heron ecology outside the nests for this population. During the breeding season we lack an understanding of their overall home range that includes foraging and roosting sites. Patterns of use of local aquatic habitats and extent of flights to foraging habitats would be beneficial. A study conducted by Kevin Alexander's students at Western Colorado University in collaboration with the Bureau of Land Management and the CBLT surveyed land beneath the Slate River heronry in mid-fall 2018 to locate fish pit tags. These pit tags were inserted in fish along Tomichi Creek. Twenty-four pit tags were recovered in heronries along Tomichi Creek and the Gunnison River, but none were found in the Slate River wetlands. These data suggest that Crested Butte herons are not foraging 30 miles south, however, more data are needed to confirm these results and identify foraging locations of the Slate River herons during the nesting season. We also lack information on post-fledging habitat use and dispersal of adults and juvenile herons at the Slate River heronry.

To obtain basic data on heron demography and movements, new methods need to be employed. One approach to better survey herons is to add camera traps to several colony trees, or place these more remotely. Installation would have to occur in the post-fledging or pre-arrival time periods. Marking adult or juvenile herons would provide an opportunity to assess habitat use, foraging strategy, dispersal, migration, nest fidelity, survival and other demographic parameters.

We have virtually no information on heron habitat characteristics at the Slate River rookery. One concern is the age and health of the nesting trees and whether herons have ample live trees to move to if nest trees fall. Long-term heronries often depend on the size of the tree stand that allows for movement over time. Several trees in the stand are leaning, some are fully dead, others are partially dead. Quantifying these vegetation characteristics during the post-fledging period (starting in late August of early September) would add to our understanding of the viability of the colony tree stand and its potential for future use by herons.

Better understanding of the ecology and the biodiversity of the CBLT Slate River wetlands could involve the addition of avian point counts and developing a bird banding station. Small mammal trapping, invertebrate surveys, and floral sampling would provide details of other taxonomic groups.

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APPENDIX

Wildlife sighted in and adjacent to Slate River Wetlands

Amphibians

Chorus Frog

Birds

Mallard
American Widgeon
Gadwall
Canada Goose
American Kestrel
Osprey
Red-tailed Hawk
Sandhill Crane (flyover)
Wilson Snipe
Belted Kingfisher
Broad-tailed Hummingbird
Northern Flicker
Willow Flycatcher
American Crow
Common Raven
Black-billed Magpie
American Robin
Ruby-crowned Kinglet
Tree Swallow
Violet-green Swallow
Yellow Warbler
White-crowned Sparrow
Song Sparrow
Red-winged Blackbird
Pine Siskin

Mammals

Mink
Moose
Elk
Beaver
Muskrat
Yellow-bellied Marmot
Pine Squirrel
Golden-mantled Ground Squirrel

Photo by Noppadol Paothong

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Without thinking, I take on its stillness.
My breathing slows, focus sharpens.
Is it telepathy that shapes me,
for a moment in this bird's image?

Ginny Lowe Connor, Great Blue Heron at Elizabeth Park

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