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Ruckus on the River

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Ruckus on the River: How River Recreation affects Breeding Great Blue Herons in a mountain valley in Colorado

By

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Thesis

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ABSTRACT Anthropogenic impacts to wildlife populations represent a reoccurring theme in wildlife management as the human population expands into wild landscapes. Our study focused on a great blue heron (*Ardea herodias*) colony of approximately 20 nests uniquely located along the Slate River near Crested Butte, Colorado. This high mountain stream increasingly draws river recreationists, especially stand-up paddle boarders. Our study assessed how human activities around the Slate River influenced heron behavior. We quantified human activities through one hour observations and heron responses through behavioral sampling. High hourly rates of human activities near the heronry coincided with brood rearing and fledging. Road traffic dominated all the types of human activity during all times of day and heron seasons; however, it only accounted for 0.004% of heron disturbances. In contrast, river recreation comprised less than 1% of all the activities in the valley, but accounted for 80-100% of heron disturbances. Our research showed that watercrafts floating directly under nesting great blue herons caused hunkering, alert, and flushing behaviors in over 80% of the herons at the colony. Of the 58 observed river recreation events, individual herons exhibited disturbance behaviors 388 times, and 57 herons flushed from the nest or surrounding wetland. During floating events, herons significantly decreased time spent in self-maintenance behaviors, their predominant undisturbed behavior. Foraging, nest maintenance, brooding, and agonistic behaviors ceased altogether during river recreation events. Floating event characteristics influenced the intensity of the heron response. Events that elicited more disturbance included larger groups (greater than three watercrafts), clustered groups floating through the colony with little separation between

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watercrafts, groups with floaters standing upright on their boards, groups that produced noise, and groups that stopped underneath the colony. Our study demonstrates that river recreation can negatively impact great blue heron breeding and that spatial segregation between the birds and recreationists is required during the nesting season for effective species conservation.

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KEYWORDS *Ardea herodias*, great blue heron, stand-up paddle (SUP) board, upper Slate River, recreation impacts, wildlife disturbance.

INTRODUCTION

Impacts of human activities on animal behavior and conservation have gained attention as human activities in wild landscapes continue to increase (Janousek et al. 2021, Kolinski and Milich 2021, Foerster et al. 2021). In fact, in 2019, conventional outdoor recreation in the U.S. produced $137.5 billion in economic activity, with water recreation generating $23.6 billion (Bureau of Economic Analysis 2020). As a form of non-consumptive wildlife use, recreational activities are often assumed to harmonize with wildlife; however, a growing body of scientific literature implies that recreation often has negative impacts on wildlife and contributed to the endangerment of species (Steven and Castley 2013). In a recent review of 274 research studies, 59% showed recreation had adverse effects on wildlife (Larson et al. 2016). Species response to human activities depends on the animal group size and sociality, body condition, body size, and food availability, as well as frequency, quantity, and type of human activity (Borgmann 2010). In general, predators and those species with complex social systems respond more negatively to disturbance than herbivores or non-cooperative breeders (Tarlow and Blumstein 2007). Herons and other colonial waterbirds are gregarious predators, and therefore may be among the most vulnerable to human activities.

Numerous studies over three decades have documented adverse impacts of human activity on nesting great blue herons (*Ardea herodias*) (Vennesland 2000, Rodgers and Schwikert 2002,

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Vennesland 2010). These impacts include reduced foraging and resting periods (Gibbs and Kinkel 1997), increased nest abandonment (Pratt and Winkler 1985), increased egg and chick loss due to exposure or predation (Pratt 1977, Simpson 1984), discouragement of late-nesting pairs from breeding (Vos et al. 1985), disruption of pair bonds (Klein 1993), decreased energy intake (Rodgers and Schwikert 2002), and increased vigilance, flushing, and flush duration (Traut and Hostetler 2003). In some instances, human disturbances resulted in reduced reproductive success (Carlson and McLean 1996, Vennesland 2000, Vennesland and Butler 2011). Foraging success is an essential factor determining reproductive success (Frederick and Collopy 1989), and when humans were in close proximity, waterbirds decreased their time spent foraging and increased vigilance (Skagen et al. 1991). Sensitive species, like great blue herons, may find it challenging to secure adequate food as their preferred foraging habitat becomes fragmented and recreation-related disturbances increase (Pfister et al. 1992, Burger and Gochfeld 1998).

Over the last ten years, human activity in the Gunnison Basin in southcentral Colorado has increased (Lieberman 2016), with water sports such as stand-up paddle (SUP) boarding becoming more popular. The upper Slate River stretch, near Crested Butte, offers a serene and scenic float through the meandering river valley protected for its natural values. In 2012, approximately ten people were observed floating on the upper Slate River, whereas five years later, over 100 floated the same stretch (Tim Szurgot, personal communication). Along the banks of the Slate River, in the riparian tree canopy, a great blue heron colony has persisted for

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over 20 years. As interest in river recreation in Crested Butte has increased, the pressure on the heronry has also increased and the timing of nesting activities in our study system coincided with optimal river flows for river recreation.

We initiated this study in 2018 to address concerns of the Crested Butte Land Trust (CBLT), the Slate River Working Group, and local stakeholders regarding the increase of recreation on the productivity and persistence of the upper Slate River great blue heron breeding colony. Colonial waterbirds (Kushlan 1993) and herons (Erwin and Custer 1982) may be ideal indicator species for monitoring ecological health and functionality because aquatic predators require high-quality foraging habitat and a fixed breeding location to be successful. We aimed to: 1) quantify human activity in Slate River Valley among years, heron breeding seasons, and times of day, and 2) quantify the impacts of human recreational activities on great blue heron behavior.

METHODS

Study Area

We studied two small great blue heron sub-colonies in a rookery less than 3 km (1.9 miles) northeast of Crested Butte, CO, in the Slate River Valley. The rookery was located on the banks of the upper Slate River in the reach between Gunsight Bridge and the river's confluence with Coal Creek. This glacial valley is dominated by a mosaic of riparian and wetland habitats interwoven with small human properties and developments. The nesting site was located on land owned and managed by the CBLT, and nearby landowners that abut this site retain conservation easements held by the CBLT. Rookery nests are located in lodgepole pines (*Pinus contorta*)

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about 12 m (40 feet) above the banks of the Slate River. Therefore, when river recreationists float this section of the river, they inevitably travel directly under the heron nests occupied from mid-March until mid-August or early September.

We conducted heron observations from three locations and observers determined which location offered the best vantage point of the herons for the time of day and weather conditions (Figure 1, Figure A1). The Slate River Road site was located on County Road 752 at a pull-off about 230 m east of the colony. The Elk Run site was located on private property on the southwest-facing slope of Smith Hill, about 340 m east of the colony. The Slate River Road and Elk Run sites were preferable for morning observations when the colony was not backlit by the sun, and the Elk Run site was advantageous for its height overlooking the colony, Slate River, and road traffic. The Wildbird site was located 190 m from the lower Colony and 240 m from the upper Colony on the southwestern side of the river atop an elevated and forested moraine, allowing for optimal views in the afternoon and evening. When approaching the Wildbird site, we took special precautions to reduce impacts to foraging herons, such as approaching from an indirect angle, moving slowly (less than one step per second), maintaining silence, and staying under tree cover along the moraine. On two occasions, we observed foraging herons flush and either return to their nest, find a different local foraging site, or circle back to the pond. We never instigated a disturbance response from nesting herons when approaching from the Wildbird site.

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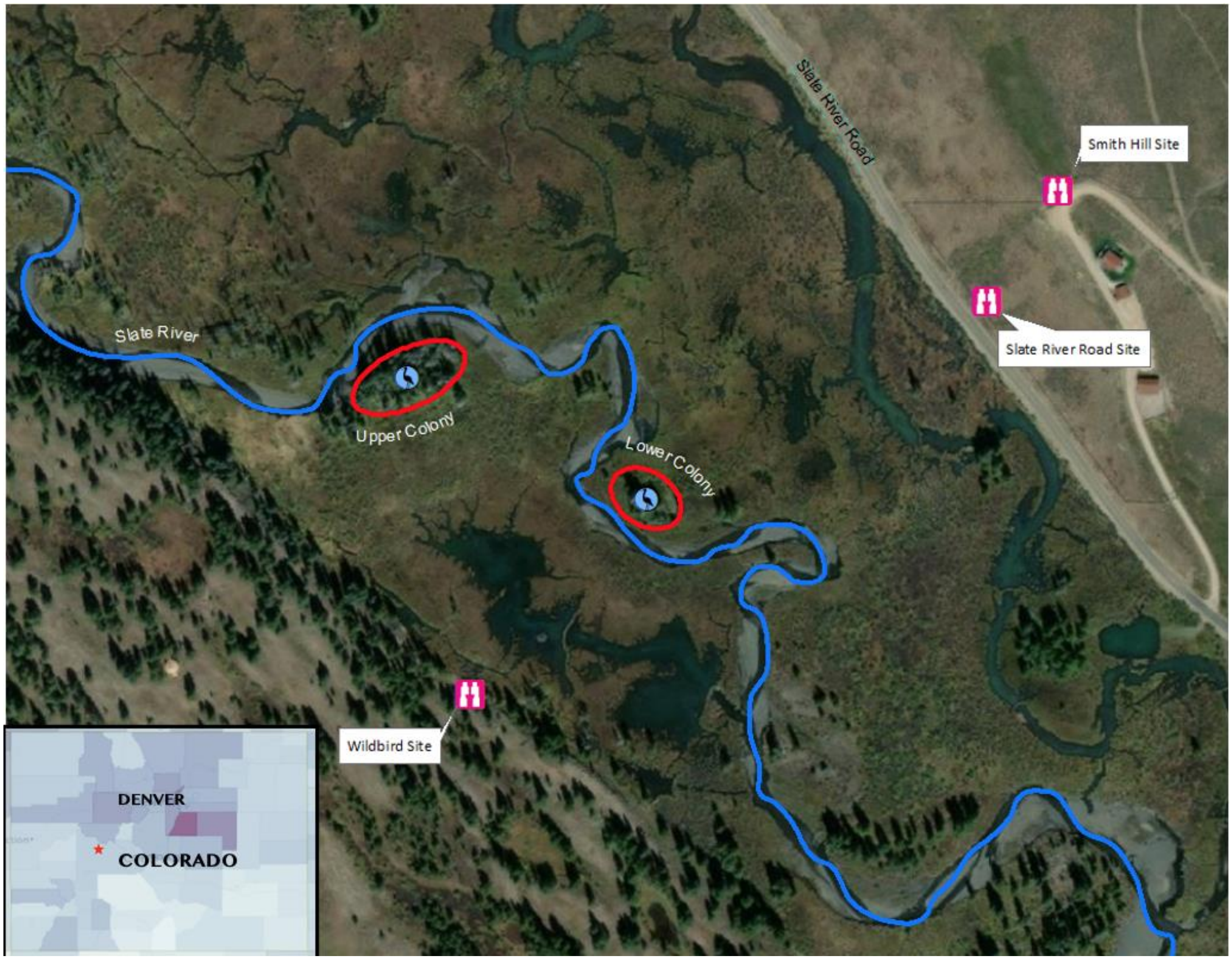

Figure 1. Aerial view of the Slate River heronry (upper and lower sub colonies are circled in red) as well as three observation sites (pink binocular symbol). The inset map of Colorado shows the location of Crested Butte with a red star. The Slate River flows from left to right in the photo. Google Earth base imagery.

Human Activity Sampling and Heron Disturbance

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We conducted 1-hour surveys to document human activities within 500 m of the heronry over three years (2018, 2019, and 2020). In 2018, surveys started in May and extended through the nesting season, whereas in 2019, surveys began in April. In 2020, we collected data with the arrival of the first heron at the colony in mid-March and continued daily until the last heron fledged and left the valley in August. We classified human activities into seven main categories, including 1) vehicles, 2) bicycles, 3) hikers and runners, 4) motorcycles, 5) river recreation (watercrafts), 6) airplanes and helicopters, and 7) winter recreation (Table A1). Air traffic was only recorded in 2018 and 2020, and winter recreation was only recorded in 2019 and 2020. For the hour long observation, we tallied human activities by category and also recorded loud noises accompanying any of the events (e.g., construction, chainsaws). We observed heron behavior and documented disturbance behaviors (vigilance or alert posture, hunkering, and flushing) in response to human activity.

River Recreation and Heron Disturbance

To quantify river recreation we made additional observations using a spotting scope from a distance of 300 m or more to view watercrafts passing below the heronry. We recorded each group of floaters (consisting of one or more individuals and watercrafts) as a "floater event" and collected information about each event as "floater characteristics." In 2018, floater characteristics included the number and type of watercrafts, number of individuals present, and dog(s) presence. Heron behavior was documented during the floating events as no change, alert posture (vigilant), and flushing. In 2019, we used radios to communicate with the CBLT

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interpretive assistant located at the put-in when a floater event launched. Once the floating event arrived at the heronry, we documented the following floater characteristics: float duration, stopping events (when floaters stopped or walked their craft beneath the colony), noise level, the distance between floaters, the profile of the floaters, and adherence to safety regulations, as well as the number and type of watercrafts, number of individuals, and number of dogs. We documented the total number of heron response behaviors for each age-appropriate behavior (adult alert, chick alert, chick hunkering, and adult flushing). We also recorded flush duration, or how long a flushed heron remained away from the colony after being flushed.

In 2020, we recorded similar floating characteristics as in 2019, but we used scan sampling to document heron behaviors before, during, and after a floater event. We observed a narrow section of the river where vegetation cover was reduced and allowed a relatively clear view of oncoming floaters. Once watercrafts were observed in this limited view or 10 minutes after a floating event launched, we conducted a "pre-disturbance" scan to collect baseline heron behaviors before floaters entered the colony. When floaters entered the colony (defined as the first observation of a watercraft upstream of the location of the first or northernmost nesting tree in the upper colony), the observer conducted a "disturbance" scan. When a floater group exited the colony (defined by a private property sign downriver from the lower colony), the observer waited a minimum of 5 minutes and subsequently conducted a "post-disturbance" scan. Scans started at the northernmost nest in the upper colony and progressed through every nest to the lower colony and included herons present in the wetlands. During each scan, we recorded

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weather conditions, observer, date, time, and the behavior of every heron present in the colony and herons in adjacent habitats. We grouped heron behavior for our analysis into ten categories: foraging, self-maintenance, nest maintenance, courtship, incubation, brood rearing, agonistic, hunkering, vigilant, and flushing (Table A2). We quantified a colony time budget by summing each behavior category observed and dividing those by total herons included in the scan and reported behaviors as percentages.

Data Analysis

We summarized the seven human activity categories documented in the 1-hour surveys and reported the rate of activities per hour. We also calculated the percent of total activities by each category of human activity. The three years of 1-hr disturbance surveys were consolidated to compare hourly rates of human recreation by year, heron season, and time of day. We designated heron seasons with non-overlapping dates to approximate heron phenology. The four heron seasons were nest building and courtship (15 March to 2 April), incubation (3 April to 1 May), brood-rearing (2 May to 2 July), and fledging (3 July to 2 September). The beginning date for each heron season corresponded to the first observation of that behavior (e.g., 3 April was the first observation of incubation). We also sampled herons throughout the day in eight 2-hour time bins: 0500-0700 (early morning), 0700-0900 (mid-morning), 0900-1100 (late morning), 1100-1300 (early afternoon), 1300-1500 (midafternoon), 1500-1700 (late afternoon), 1700-1900 (early evening), and 1900-2100 (late evening). River recreation results were analyzed independently for each year. In 2018, we quantified the number of floater events that led to heron disturbance

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behaviors. In 2019 and 2020, we summarized total events, total crafts, craft types, total people, noise and stoppage events, and heron responses. We assigned numerical ranges to the floater event characteristics based on the different levels of the characteristic (Table 1). Group size, number of crafts, number of people, and float duration were analyzed as continuous variables while stopping, noise level, floater profile, and floater density were analyzed as discrete values. We tested whether heron response differed in relation to the total crafts, float duration, group density, floater profile, noise events, and stoppage events. For the 2020 scan samples, we summarized the frequencies of heron behaviors observed by scan type: pre-disturbance, disturbance, post-disturbance.

Table 1. Floater event characteristics describe behaviors of river recreationists on the Slate River in 2019 and 2020.

Floater Event Characteristics
Group Size The total number of watercrafts, total number of people, and total number of individuals per craft. - *Counted for each event.* Presence of dogs in the party. - *Documented as Yes or No.*

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Floater Speed

The duration of a floater event from entry in upper colony to exit below lower colony.

- *Timed with cell phone and recorded in minutes*.

Stopping

Incidences when floaters stopped and/or exited their crafts, as well as if they walked and dragged their crafts through the colony stretch.

- *0 = no, stopping did not occur*
- *1 = yes, stopping did occur*

Noise

Audible sounds were detected at observation site >300 m northeast of the colony. Volume qualitatively assessed in three categories: silent, moderate, and loud. Each floating event was described as quiet, talking, or yelling present, music present, scraping rocks when walking and dragging watercraft along stream bottom.

Low-moderate noise was not considered to be a noise event and loud volume was considered a noise event.

- *0 = no, a noise event did not occur*
- *1 = yes, a noise event did occur*

Density and Distancing

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Measure of how clumped watercrafts were when floating through the colony. Categories included a single floater or well-spaced group in which crafts were >10 feet apart, watercrafts more than 5 feet apart but within 10 feet of each other, watercrafts within 5 feet of each other and/or joined together.

- *1 = well-spaced group > ~10 feet of separation between crafts or single floater*
- *2 = crafts within ~10 feet of one another*
- *3 = crafts ~5 feet from one another or crafts are joined together*

Floater Profile

Posture of individuals on each craft as they floated through colony. From most upright to least: standing, kneeling, or using high oar/paddle movements, sitting, or prone on craft.

- *1 = sitting/prone*
- *2 = kneeling*
- *3 = standing*

Adherence to River Safety Regulations and Respect for Heronry Protocols

Indicated whether individuals carried and wore personal floatation devices (PFDs).

- *Documented as Yes or No*

We used a non-parametric χ^2 test of independence to determine if associations between categorical variables existed, which would point to non-independent data. We employed non-parametric Mann-Whitney U tests for two-sample comparisons and Kruskal–Wallis H tests with

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post-hoc Dunn tests for three or more sample comparisons to determine if there was a significant difference: 1) in the rates of human activities among the three years, 2) among seasons, and 3) among times of day, 4) between heron response and floater event characteristics and, 5) between the frequencies of colony behavior and scan type. For all analyses, we used alpha = 0.05.

RESULTS

Human Activity in the Slate River Valley

River recreation accounted for less than one event per hour and less than 1% of all human activities observed in the Slate River valley in 2018, 2019, and 2020 (Table 2). Most human activity occurred on the Slate River Road, with vehicles accounting for 83-88% of total activities. Bicycles were the second most abundant and accounted for 10-14% of activities across years. Motorcycles along with hikers and runners accounted for less than one event per hour in all three years. Airplanes and helicopters passed over the colony at four events per hour in 2018, whereas in 2020, we observed less than one event per hour.

Table 2. Total counts of human activities, percentages, and the number of events per hour in the vicinity of the Slate River heron colony near Crested Butte, Colorado for all three years. We did not collect winter recreation data in 2018, and in 2019, we did not collect data on airplanes and helicopters, so these two categories are not included in percentages. ND = no data.

Year	**2018**	**2019**	**2020**

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Hours of observation	*N=59*			*N=136*			*N=187*		
Human Activity	Total	%	Events /hr	Total	%	Events /hr	Total	%	Events /hr
Vehicles	2,718	82.8%	46.1	5,659	82.6%	41.6	7,260	87.7%	38.8
Bicycles	459	13.9%	7.8	969	14.2%	7.1	793	9.6%	4.3
Hikers and runners	51	1.6%	0.9	88	1.3%	0.6	129	1.6%	0.7
Motorcycles	47	1.4%	0.8	106	1.5%	0.8	90	1.1%	0.5
River recreation	7	0.2%	0.1	25	0.4%	0.2	6	0.1%	0.03
Total	3,282	99.9%	55.6	6,847	100.0%	50.3	8,278	100.1%	44.2
Airplanes and helicopters	226	-	3.8	ND	-	ND	161	-	0.9
Winter recreation	ND	-	ND	3	-	0.02	8	-	0.04

Human Activities Relative to Heron Season

We conducted 13 hourly surveys during nest-building, 35 during incubation, 152 during brood rearing, and 180 during fledging. The rate of vehicles (62 events per hour) were highest during

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the fledging stage along with bicycles (8 events per hour), motorcycles (1 event per hour), airplanes (1.5 events per hour), and river recreation (0.2 events per hour). Hikers and runners (1 event per hour) along with winter recreation (0.4 events per hour) peaked during the nest building stage. The rate of vehicles ($H = 148.1$, $df = 3$, $p < 0.0001$), bicycles ($H = 43.3$, $df = 3$, $p < 0.0001$), hikers and runners ($H = 10.3$, $df = 3$, $p = 0.02$), motorcycles ($H = 47.0$, $df = 3$, $p < 0.0001$), airplanes ($H = 16.0$, $df = 3$, $p = 0.001$), and winter recreation ($H = 72.4$, $df = 3$, $p < 0.0001$) differed significantly by heron season. More specifically, the rate of vehicles (brooding: $p < 0.0001$, fledging: $p < 0.0001$), bicycles (brooding: $p = 0.02$, fledging: $p = 0.0004$), motorcycles (brooding: $p < 0.0001$, fledging: $p < 0.0001$), and airplanes (fledging: $p = 0.006$) was significantly higher during brood rearing and fledging whereas hikers and runners ($p = 0.007$) and winter recreation ($p = 0.003$) were significantly higher during nest building. River recreation was not observed during the nest building and incubation seasons.

Human Activities Relative to Time of Day

We completed 39 hourly surveys during early morning, 39 in mid-morning, 61 in late morning, 68 in early afternoon, 88 in midafternoon, 64 in late afternoon, 29 in early evening, and 5 in late evening. Air traffic (1.6 events per hour) was observed at the highest rate in the mid-morning and hikers and runners (1.1 events per hour) peaked in the late morning. Bicycles (10 events per hour), and river recreation (0.2 events per hour) peaked in the early afternoon. Vehicles (58 event per hour) and motorcycles (1 event per hour) were observed at the highest rate in the midafternoon. The rate of vehicles ($H = 92.7$, $df = 7$, $p < 0.0001$), bicycles ($H = 93.2$, $df = 7$, $<$

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0.0001), motorcycles ($H = 35.9$, $df = 7$, < 0.0001), and airplanes ($H = 23.9$, $df = 7$, $p = 0.001$) differed by time of day. The rate of vehicles was significantly lower in early ($p < 0.0001$) and mid-morning ($p < 0.0001$), but was the dominant human activity in the upper Slate River Valley at all times of the day. Bicycles were also significantly lower during the early ($p < 0.0001$) and mid-morning ($p < 0.0001$). Motorcycles were significantly lower during the early morning ($p = 0.0003$) and late evening ($p = 0.02$). River recreation was only observed between the late morning and late afternoon.

Heron Response Summary

Over the three years of the study, we documented 180 occurrences of herons responding to stimuli with disturbance behaviors (Table 3). Of those, 63 were vehicle events, and 60% (n = 38) of these were associated with a loud noise (emergency vehicle sirens, commercial trucks, trailers slamming). Over the three years of the study, however, vehicles elicited heron responses only 0.004% of the time. In contrast, river recreation accounted for less than 1% of human activities and elicited heron responses 100% of the time. The vast majority of human activities occurred on the Slate River Road at a distance greater than 300 m from the colony. River recreation occurred in close proximity, directly below the colony. Cross country skiing was the only other activity within 300 m of the colony.

Table 3. The number of great blue herons in disturbance behaviors in response to human or animal activities recorded during hourly observations, within 500 m of the Slate River heronry

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summarized for all 3 years. The number of events refers to the total number of events in which we observed at least one heron response behavior.

Event Type	Year(s) Observed	# of Events	Adult Alert	Chick Alert	Chick Hunkering	Flushing
Vehicles	2018-2020	63	14	400	0	1
River Recreation	2018-2020	58	48	153	130	57
Airplane/Helicopter	2018, 2019	19	1	74	0	0
Motorcycles	2018, 2019	11	0	52	0	0
Bicycles	2018	8	0	14	0	0
Hiker/Runner	2018, 2019	7	0	37	0	0
Alarm/Siren	2018	3	0	9	0	0
Live Band	2018	3	0	45	0	0
Avian Predators	2019	2	1	5	0	0
Military Jet	2018	2	0	12	0	0
Cattle	2018	1	0	3	0	0

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Chainsaw	2019	1	0	2	0	0
Skier	2019	1	2	0	0	0
Thunder	2019	1	0	4	0	0
Total	-	180	66	810	130	58

2018 River Recreation and Heron Behavior Summary

In 2018, we recorded seven floating events in 59 1-hr bouts. These events occurred between 5-23 June 2018. The seven floating events consisted of 26 total people, and only one group was characterized as loud. A total of 11 adult alert behaviors, 24 chick alert behaviors, and 15 heron flushes were elicited from these seven events.

2019 River Recreation and Heron Behavior Analysis

The 44 floater events documented in 2019 consisted of 123 people on 104 total watercrafts, of which 84 were SUP boards, 9 were kayaks, 8 were duckies, and 3 were rafts. The most frequent group size was two people (17 events), followed by groups of 5 (7 events), 3 or 1 (6 events each), 4 (4 events), and finally 6 (2 events). During the 44 events, ten individuals sat or used a prone posture, 14 knelt, and 19 stood on their SUP boards while floating through the heron section (one observation lacks this information). Twenty-three herons flushed during the 44 floating events, while 108 hunkered, and 93 became alert. Of the 23 flushes, seven herons did not return to the colony for the remainder of the observation period. In contrast, two herons returned within 20 minutes, and 14 herons returned to the colony within 5 minutes of the disturbance event.

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Total chick alert varied significantly in relation to the number of crafts (H = 10.9, df = 4, p = 0.03). More chicks became alert when a floating event consisted of 5 watercrafts compared to events with one watercraft (post-hoc Dunn test, p = 0.01) (Figure 3A). Significantly more adult herons (W = 5.7, df = 1, p = 0.02) and chicks (W = 21.0, df = 1, p < 0.0001) became alert when events included loud noise (Figure 3B and 3C). Significantly more chicks became alert when floaters stopped within the colony section (W = 8.4, df = 1, p = 0.004) (Figure 3D). Chick hunkering increased significantly in relation to floater profile (H = 13.2, df = 3, p = 0.004), with standing floaters associated with higher disturbance than when floaters took a sitting/prone posture (post-hoc Dunn test, p = 0.002) (Figure 3E). Group density also was significantly associated with increased chick alert behavior (H = 11.2, df = 3, p = 0.012) (Figure 3F). Groups separated by greater than 10 feet were associated with fewer alert responses than when groups maintained less than 5 feet between crafts (post-hoc Dunn test, p = 0.01) (Figure 3F).

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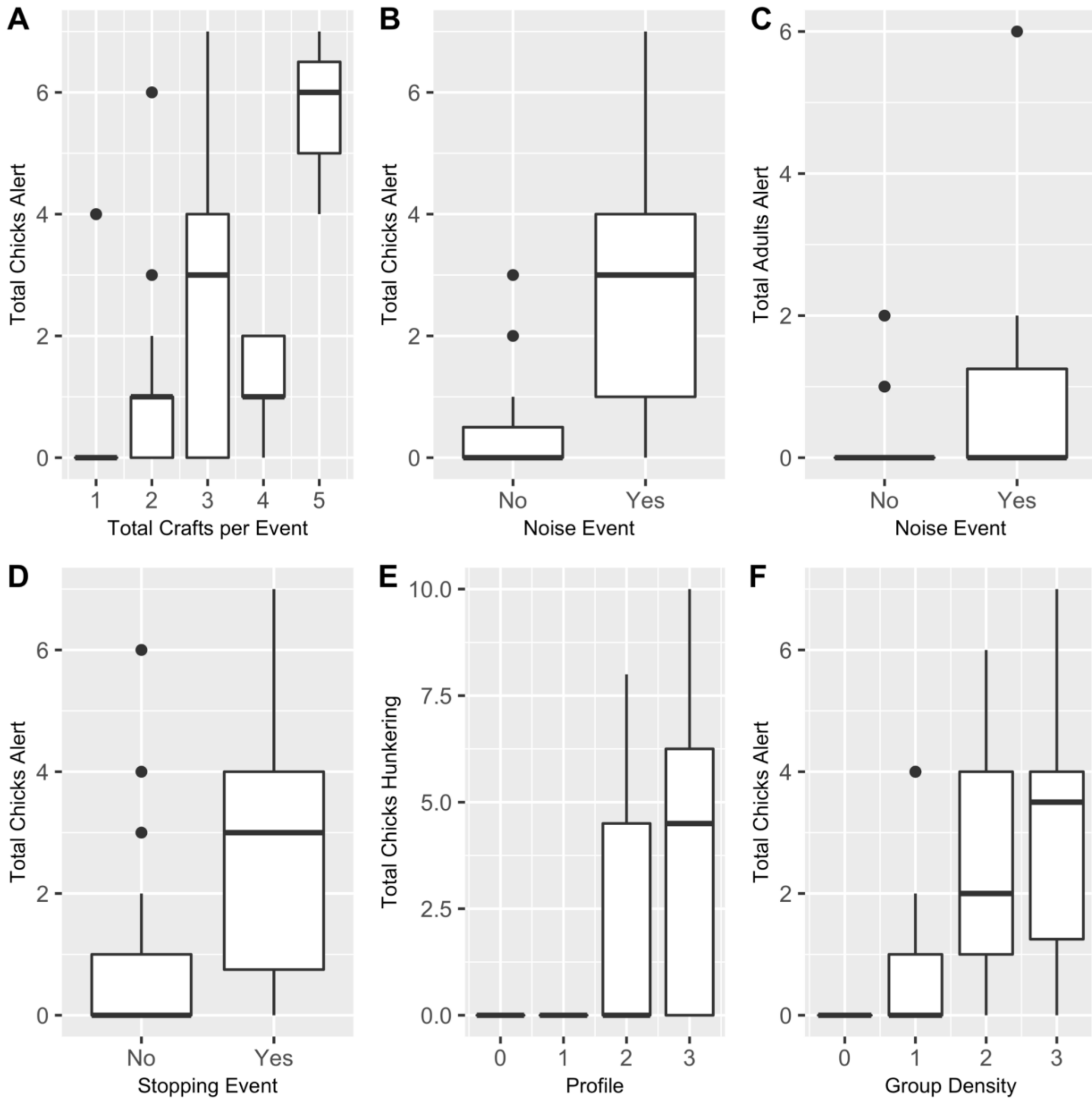

Figure 3. Adult heron or chick responses in relation to floater behaviors documented from 44 floater events. These data are counts, not percentages (e.g., during a noise event the average number of chicks becoming alert was 3). The bottom of the box plot represents the lower

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quartile while the top represents the upper quartile. The thick black line in the middle of each box represents the median. Lines extending from the boxes represent the whiskers of the plot and the dots outside the line are outliers. In figure E, 1=sitting/prone, 2=kneeling, 3=standing. In figure F, 1= floater events consist of crafts spaced more than 10 feet apart or a single floater, 2= crafts within 10 feet of one another, 3= crafts separated by 5 feet or less or crafts are joined together.

2020 River Recreation and Heron Time Budget Analysis

The seven floater events we observed in 2020, consisted of 19 people on 16 crafts (13 SUP boards, 2 kayaks and one raft). Six people sat on their craft, eight knelt, and five stood. The average float duration was 9.2 minutes, with the fastest float duration of 4 minutes and the longest 16 minutes. Three groups were spaced with greater than 10 feet between crafts, one group was within 10 feet of one another, and one group was within 5 feet (we lacked observations of density for two events). All seven groups were characterized as quiet, and only one group had a dog. All but one group had PFDs onboard and all but one of those wore their PFDs. An average of 5 herons flushed per event, and 19 total flushes were observed for the seven events.

Over 80% of herons in the colony enacted disturbance behaviors (hunkering, alert, or flushing) during floating events (Figure 4). Vigilance ($H = 11.5$, $df = 2$, $p = 0.003$) and flushing ($H = 7.9$, $df = 2$, $p = 0.02$) were statistically higher during disturbance scans compared to pre-and post-disturbance scans. Further, some herons (3.9%) hunkered during disturbances, but no herons

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hunkered pre-disturbance or after floaters passed through the colony (this difference was not statistically significant: $H = 4.9$, $df = 2$, $p = 0.09$). Herons spent 88.1% and 90.5% of their time in self-maintenance behaviors during pre-and post-disturbance, respectively, whereas they only spent 16.6% of their time in self-maintenance during disturbance ($H = 7.8$, $df = 2$, $p = 0.02$). Though not statistically significant, herons spent 1.6% of their time foraging prior to a floating event, 0% during, and 0.5% after an event . All other non-disturbance behaviors declined during floating events (Figure 4). The total number of watercrafts per floater event, the total number of people per floater event, float duration, and group density did not significantly affect the frequencies of heron alert behaviors. It was not surprising these relationships remain unclear due to the small sample size.

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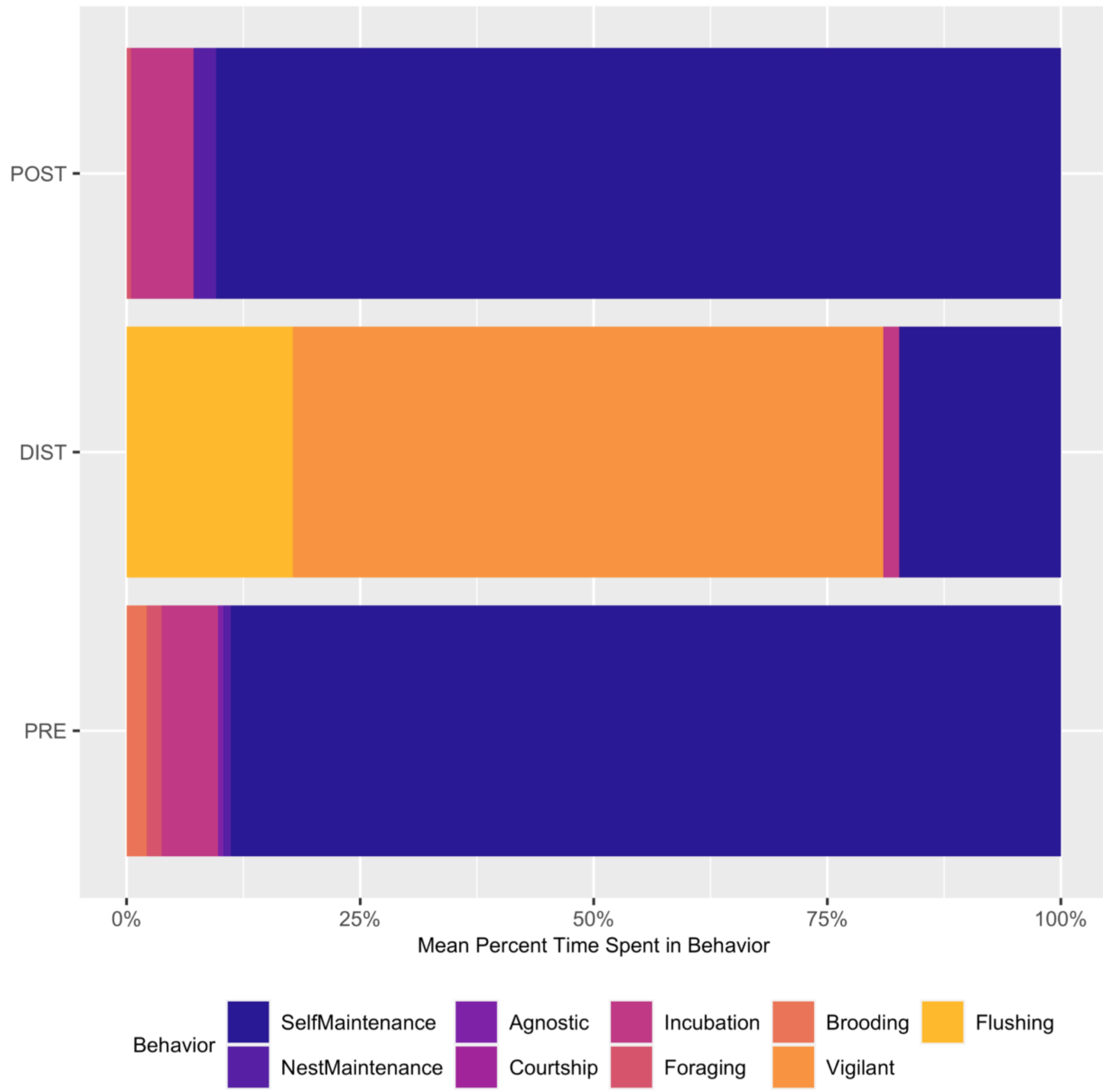

Figure 4. Frequencies of heron behaviors documented before (PRE = Pre-Disturbance), during (DIST = Disturbance), and after (POST = Post-Disturbance) the seven documented river

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recreation events in 2020. These data represent the 4 complete sets (pre, disturbance, and post) of scan sampling.

DISCUSSION

Research Implications

While river recreation accounts for less than 1% of the human activities in the upper Slate River Valley, it accounts for 80-100% of heron disturbances. Our research shows that river recreation occurring directly under nesting great blue herons leads to a shift from non-disturbance to disturbance behaviors (hunkering, alert, flushing) in 80% of the herons attending the colony. Our observations confirm that adult flushing is a common response to approaching watercrafts. Similar results were found when slow-moving crafts drifted directly under nesting great blue herons on the Roaring Fork River in Pitkin County, Colorado (Lowsky 2018), and in northcentral Colorado (Vos et al. 1985). Other studies that have documented bird activity budgets reported reduced foraging, self-maintenance, nest maintenance, brooding, and sleeping in response to humans being nearby (Henson and Grant 1991, Steidl and Anthony 2000, Tarjuelo et al. 2015). In this study, during river disturbances, the colony altogether ceased foraging, nest maintenance, brooding, and agonistic behaviors, and self-maintenance and incubation steeply declined. In addition to behavior changes by herons in response to disturbance, numerous researchers concluded that human activity near great blue heron rookeries leads to reduced use of preferred habitats (McGarigal et al. 1991, Klein 1993). The Slate River wetland complex provides access to nearby foraging habitats with appropriate adjacency to the nest site. This proximity of nests to

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foraging grounds provides an important energetic advantage to a heronry, but human presence can significantly reduce the value of heron foraging habitats (Lowsky 2018). On Sanibel Island in Florida, a high density of canoeists apparently shifted the use of the favored main channel to the use of backwaters by herons (Klein 1993). Our study documented the interruption of foraging behaviors associated with watercrafts floating adjacent to the Slate River wetlands, and during post-disturbance scans, most herons did not resume foraging for more than 10 minutes after an event.

Increased stress and decreased energy intake can potentially reduce the survival of offspring (Anderson and Keith 1980) and lower colony productivity. In a review of the effects of disturbance on birds, 90% of studies showed a reduction in breeding success by a mean of 40% in the face of disturbance (Hockin et al. 1992). Although Slate River herons successfully fledge young, the survival and recruitment of herons depend on numerous factors, including the nutritional status of young before and when they fledge (Both et al. 1999, Green and Cockburn 2001). We only have three years of colony size data for the Slate River herons, but at this time, the colony declined from 25 active nests in 2018 to 18 in 2020. Overall, our data combined with previous research in other locations point to the incompatibility of human recreation in proximity to great blue heron nesting colonies.

Habituation

Some evidence suggests great blue herons are capable of habituation to human activities, but this response seems to be context-dependent. For example, heronries in more urban settings have

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shorter flush distances than those in rural areas (Vennesland 2000). Also, where abundant food bonanzas occur, the heron threshold for disturbance may increase (Vennesland and Butler 2011). Little evidence supports the habituation of herons when unpredictable events occur in close proximity to the colony or when loud noises accompany these events (Lowsky 2018). Our study occurred in a rural open space area adjacent to a small mountain town in the absence of any proximate food bonanzas. The area has a relatively silent background acoustic landscape, and noises elicited chick and adult heron alert behaviors. Noise impacts on wildlife include altered habitat use and activity patterns, increased stress, decreased immune response, reduced reproductive success, increased predation risk, and damaged hearing if the sound is sufficiently loud (Bowles 1995, Larkin et al. 1996). Floating events in our study occurred directly below the nests and were unpredictable in timing and floater event characteristics, including noise level, therefore heron habituation to river recreation for this site seems unlikely.

Floater Protocols

Whereas the presence of river floaters at the Slate River heronry increases heron disturbance behaviors, it is unclear whether nuanced floater behaviors may dampen heron response to the event. Floater characteristics consisting of groups no larger than three crafts, with no dogs, that remained quiet while sitting, that remained on or in watercraft while moving slowly and continuously through the heronry section in single file with adequate spacing among multiple watercrafts elicited less heron disturbance responses. Public education is crucial because people are more likely to support restrictions and protocols if they understand how wildlife will be

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impacted both negatively and positively by their actions (Buell 1967, Seketa 1978, Shay 1980, Duda 1987, Purdy et al. 1987). For example, a study conducted to investigate the behavioral responses of waterbirds to human disturbances found visitors who spoke to refuge volunteers were less likely to disturb wildlife than other recreationists (Klein 1993). Comparably, in the river use study conducted by the Crested Butte Land Trust, river stewards found that 42% of potential floaters decided not to float the upper Slate River after talking to the river stewards and learning about the potential to disturb the heron colony (Cheryl Cwelich and Erin Blair 2020, personal communication). While management actions that influence floater behavior may be promising, the effectiveness of these measures in conserving great blue herons is not currently known and needs further study.

Management Implications

Our data suggest river recreation has the greatest negative impact on heron behavior of any human activity in the valley, likely due to the proximity of floaters to the nests. The most effective strategy recommended in the literature to provide functional breeding habitat for great blue herons is the establishment and enforcement of a 300 m spatial buffer (Gebauer and Moul 2001) or 65-300 m quiet zone (Lowsky 2018) around the colony. Due to the nature of public river access, temporal restrictions represent an alternative to a spatial buffer. Beginning in 2019, the Slate River Working Group implemented a voluntary no-floating period from 15 March to 15 July, the ending coincided with the date when 50% of the heron chicks had fledged. In years with high snowpack and subsequent high river flows, floating opportunity extends beyond the

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voluntary no float period. In drier years, low river flows preclude river recreation before the voluntary no-float period expires. The temporal and voluntary no float period severely limits access by recreationists to the river, however, the voluntary nature of the closure means that at least some recreationists choose their desire to float over the protection of the heronry. Floating during the voluntary no float period coincides with incubation and the early guardian stages of brood rearing, times when eggs and nestlings are especially vulnerable (Quinney 1982, Vos et al. 1985, Butler 1992). Though the Slate River heronry is treacherous to access on foot, angling and nordic skiing have been observed in the Slate River wetlands within 300 m of the colony. Management strategies that prohibit fishing and skiing within the vicinity of the heronry could be considered to reduce potential disturbances within a 300 m buffer. To proactively reduce the potential for negative impacts, the Crested Butte Nordic Center now closes portions of their trail system in mid-March in anticipation of the herons' return.

Heronry persistence has been linked to the size of the heronry, with colonies consisting of less than 20 nests persisting for less than a dozen years (Kelley et al. 2006). The Slate River colony dropped to 18 active nests in 2020, falling below the 20-nest threshold that predicts longer persistence. A cascade of events can lead to colony abandonment: when human activities encroach on herons, nest trees decline in health, mammalian and avian predators torment herons, and stochastic weather events such as hailstorms and strong winds occur simultaneously (Von Duyke 2006). These scenarios paint a picture of the fragility of the Slate River heronry that includes many uncontrollable events. Sound conservation requires acting on threats that are

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within the control of managers and stakeholders. Our data, combined with a conclusive body of literature and current population trends at the Slate River heronry points to the need to enact temporal and spatial protections that bolster the probability of persistence of this heron colony.

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APPENDIX A. SUPPORTING INFORMATION

Table A1. Human activities within 500 m of the heronry recorded during 1-hour activity surveys at the Slate River great blue heron colony near Crested Butte, Colorado from 2018-2020.

Human activities	Description
Vehicles	Any motorized vehicle other than motorcycles
Bicycles	Mountain bikes and road bikes observed on the Slate River Road and on the Smith Hill trail
Hikers and runners	Pedestrians hiking or running on the Slate River Road, on the trails behind Wildbird, and on the Smith Hill trail
Motorcycle	Street motorcycles and dirt bikes on the Slate River Road
River recreation	River recreation included all watercraft such as stand-up-paddle (SUP) boards, kayaks, duckies, rafts, and canoes in the Slate River
Airplanes and helicopters	Planes and helicopters that flew over the colony
Winter recreation	Winter recreation included cross country skiers, snowmobiles, and grooming snowcats for the Crested Butte Nordic Center

Table A2. Great blue heron behavior categories (ethogram) used for scan sampling at the Slate River heronry in 2020. The ethogram represents a combination of behaviors previously

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*documented in herons (Mock 1972) and behaviors that we combined consistently based on our observations in 2019 and 2020 into broader categories***.**

Behavior Categories	Behavior Description – *includes all age classes*
Foraging	Wading, shoreline scanning, pre-strike posture, striking, "gleaning", hovering, eating/processing food, juveniles practice foraging, chicks beg for food from adult, chicks eating directly from parent's bill, chicks eating off nest floor
Self-Maintenance	Adult and chick preening, sun-bathing, gular fluttering, sleeping, bill filing/cleaning, bugging/swatting, defecating, walking, flying, wading/swimming, laying, sitting hunched, sitting up, standing hunched, standing up, standing with head tucked under wing, juvenile test flaps/flying
Nest Maintenance	Nest building, nest maintenance
Courtship	Stretch, snap, wing preen, circle flight, landing call, twig exchange, twig shake, crest raising, fluffed neck, bill-clappering, bill duel, courting mount/false copulation, copulation
Incubation	Incubating, attending to eggs
Brood Rearing	Attending to chicks, disposal of chick waste, molt/plumage grooming, feeding chicks or juveniles

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Agonistic	Adult spreading-wing display, vertical display, forward display, bill duel, circle flight, supplanting, chick bullying/aggression/territoriality, siblicide
Hunkering	Sitting low in the nest to avoid detection
Vigilant	Alert posture, head straight up, scanning
Flushing	Departing from the nest in flight in response to stimuli

Figure 2A. The Slate River heronry from the vantage of Smith Hill Road to the east. The main current of the Slate River is traced in dark blue and flows from right to left in the photo. The upper (on right) and lower (on left) sub colonies are circled in light blue and are separated by roughly 128 m. The inset photographs, outlined in light blue, show up-close images of the sub colonies. The inset map of Colorado shows the location of Crested Butte with a red star. Photos were taken 7 October 2020 by Alex Stogsdill.

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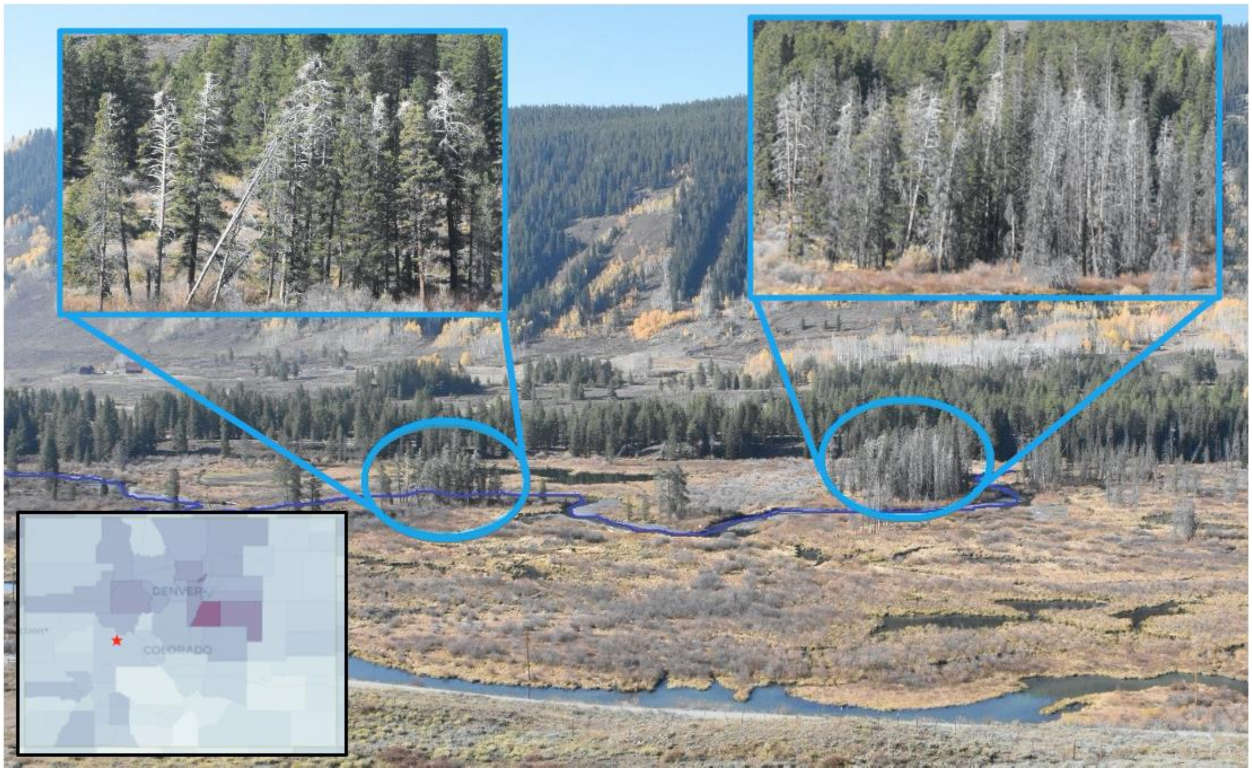

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Treetops High in the Mountains: Breeding behavior of nesting great blue herons (Ardea herodias) in Colorado

By

Ellie Orr

Thesis

Presented to the Faculty of MS in Ecology

Western Colorado University

in Partial Fulfillment of the for the Degree of

Master of Science

Western Colorado University

Gunnison, Colorado

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ABSTRACT

The Great Blue Heron (*Ardea herodias*)is the largest semi-aquatic wading bird in North America and nests in gregarious colonies. Our study concerns a unique high elevation breeding heronry located in the Slate River Valley near Crested Butte, Colorado. The purpose of our study was to document great blue heron behaviors by implementing scan and focal sampling techniques. We developed a behavioral ethogram with 60 potential heron behaviors and quantified colony and individual heron time budgets. Herons in this study's time spent in behaviors varied intrinsically and temporally. This colonies precent time conducting mandatory life cycle behaviors was asynchronous across the colony (staggered arrival and initiation of breeding). We also uncovered some behaviors significantly differed by time of day, but this colony showed no distinct diel pattern in behavior. This behavioral study adds to the knowledge of inland high elevation nesting great blue heron behavior, which has received little to no attention in the literature. It reveals insight on how great blue heron behavior varies intrinsically and temporally, while also revealing potential stressors to this colonies future reproductive success and providing management strategies for dealing with these stressors.

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KEYWORDS *Ardea herodias*, great blue heron, Slate River, breeding behavior, high elevation

INTRODUCTION

The great blue heron is the largest and most widespread wading bird in North America. Great blue herons are solitary hunters that nest and raise their young in gregarious colonies. Our study concerns a persistent great blue heron (*Ardea herodias*) nesting colony located near Crested Butte, Colorado. This colony uniquely resides in two high elevation (2,700 m/8,900 feet msl) stands of lodgepole pines (*Pinus contorta*) along the Slate River. The literature currently lacks documentation of nesting great blue herons in high mountainous systems. Through our study we hoped to document great blue heron nesting behaviors and understand the role age and temporal factors may play in how herons spent their time.

Reproductive and behavioral studies on great blue herons have been conducted by Cottrille and Cottrille (1958) in Michigan, Pratt (1970) in central California, Henny and Bethers (1971) in Oregon, Brandman (1976) in California, Edford (1976) in Ohio, and Stephens (1980) in Kansas, to name a few. Studies of great blue herons have found weather to be implicated in changes in foraging behavior (Bovino and Burtt 1979) and productivity (Witt 2006); while time of day can affect overall activity (Robbins 1981). Coastal heronries rely on daily changing tidal patterns that drive feeding and other behaviors (Matsunaga 2000), whereas inland heronry activity corresponds to time of day (Robbins 1981, McNeil et al 1993). Feeding behaviors are also driven by abrupt increases in seasonal requirements of parents and their young (Matsunaga 2000, Pratt 1970).

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The purpose of our study was to quantify the behavior of great blue herons at the upper Slate River rookery, to develop a baseline time budget for the population as a reference point to assess future changes in the valley. It is well known that annual cycles of species are often related to abiotic conditions such as temperature, temporal and spatial patterns of resources, and day length (Ferguson and Elkie 2004, Birkett et al 2012). In the case of this high elevation heronry, annual snowmelt date acts as an environmental indicator and drives water flow for quality foraging habitat (Grau and Parris 1980) needed to fulfill seasonal energy requirements (Matsunaga 2000, Pratt 1970). High mountainous systems are of high concern due to these systems being exposed to the early symptoms of climate change (Viviroli et al 2011). In addition, this heronry is also pressed with the increase in human presence in this once undisturbed valley. Therefore, a detailed multi-year behavioral study of great blue heron breeding behavior that investigates the potential effects of temporal factors could uncover possible vulnerabilities of this species to changes in weather patterns and increased human presence.

We created an ethogram for adults and chicks and used it to study heron behavior using scan and focal sampling methods. Further, we quantified behavior in relation to heron age class, seasonal stage and time of day. We hypothesized heron behaviors would be observed at different frequencies in relation to age class, breeding stage, and time of day. More specifically, we hypothesized chick and juvenile herons would spend more time conducting self-maintenance and in postures, while adult herons would have to distribute more time to breeding behaviors such as incubating and brooding (Cottrille and Cottrille 1958). With the knowledge of the great blue

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heron breeding cycle, we predicted that time spent performing nest maintenance and courtship would decrease, while time spent foraging, incubating, and brooding would increase as the breeding season progressed (Cottrille and Cottrille 1958). A study conducted in Oregon suggested inland heron activity is diurnal in nature, where feeding their young peaks in the morning and evening (McNeil et al 1993). This led us to hypothesize that this inland heronry would have a pattern in behavioral frequencies as the day progresses with spikes in young feeding in the morning and evening.

METHODS

Study Area

We conducted heron observations from three locations and observers determined which location offered the best vantage point of the herons for the time of day and weather conditions (Figure 1, Figure 1A). The Slate River Road site was located on County Road 752 at a pull-off about 230 m east of the colony. The Elk Run site was located on private property on the southwest-facing slope of Smith Hill, about 340 m east of the colony. The Slate River Road and Elk Run sites were preferable for morning observations when the colony was not backlit by the sun, and the Elk Run site was advantageous for its height overlooking the colony, Slate River, and road traffic. The Wildbird site was located 190 m from the lower Colony and 240 m from the upper Colony on the southwestern side of the river atop an elevated and forested moraine, allowing for optimal views in the afternoon and evening. When approaching the Wildbird site, we took special precautions to reduce impacts to foraging herons, such as approaching from an indirect

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angle, moving slowly (less than one step per second), maintaining silence, and staying under tree cover along the moraine. On two occasions, we observed foraging herons flush and either find a different local foraging site, or circle back to the pond. We never instigated a disturbance response from nesting herons when approaching from the Wildbird site.

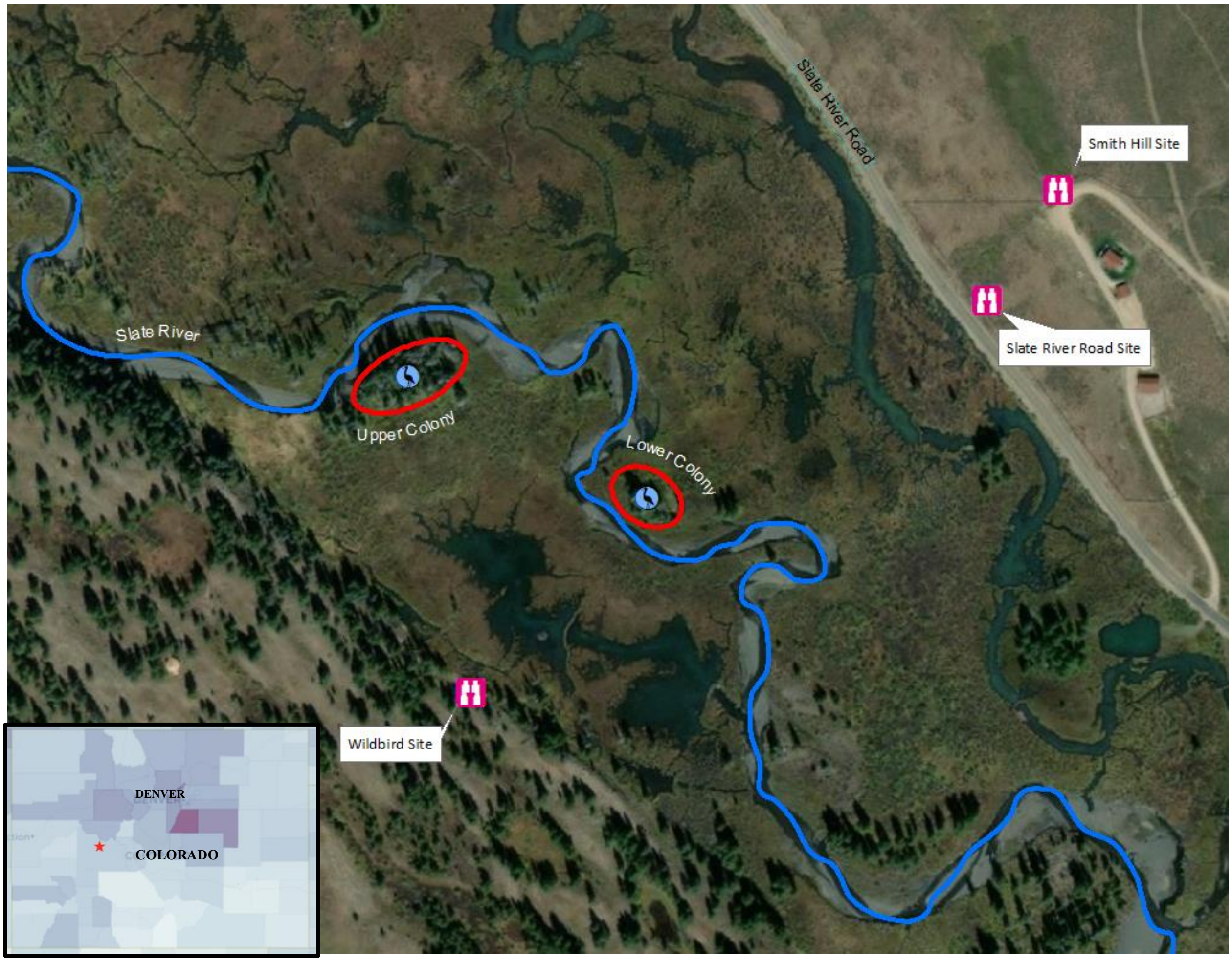

Figure 3. Aerial view of the Slate River heronry (upper and lower sub colonies are circled in red) as well as three observation sites (pink binocular symbol). The inset photographs, outlined

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in light blue, show up-close images of the sub colonies. The inset map of Colorado shows the location of Crested Butte with a red star.

The Slate River flows from left to right in the photo. Google Earth base imagery.

Study Design and Data Collection

Ethogram Development

We combined 60 behaviors recorded in 2019 and 2020 into twelve broader categories. We added additional infrequent behaviors to our ethogram in 2020 and these are represented with a 20 superscript on Table 1. The twelve broad behavior categories were: foraging and eating, locomotion, self-maintenance and posture, thermoregulating, nest maintenance, courtship, incubating, brooding, feeding the young, agonistic, alert behaviors, and out of view.

Table 1. Great blue heron behavior categories (ethogram) used for scan and focal sampling at the Slate River heronry from 2019-2020. The ethogram represents a combination of behaviors previously documented in herons (Mock 1976) and behaviors that we combined into categories based on our observations in 2019 and expanded slightly in 2020. The 20 superscripts refer to a behavior added to the ethogram in 2020.

Category	**Great Blue Heron Behaviors** - *all ages included*
Foraging and Eating	Wading/scanning, shoreline scanning, pre-strike posture, striking, "gleaning"[20], hovering[20], juveniles practice foraging [20], chicks beg for

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	food [20], processing or consuming food, chicks taking food directly from parent's bill[20], chicks eating off nest floor[20]
Locomotion	Adult walking, flying, wading/swimming, juvenile walking[20], juvenile practice flaps/flying[20]
Self-Maintenance and Posture	Adults and chicks care for their feathers by grooming with bill or feet[20], scratching, stretching, sleeping, bill filing/cleaning[20], bugging/swatting[20], excreting[20], heron body position when not performing a listed behavior including: laying, sitting hunched[20], sitting up, standing hunched[20], standing up, standing with head tucked under wing
Thermoregulating	Sun-bathing, gular fluttering
Nest Maintenance	Nest building, nest maintenance
Courtship	Stretch, snap, wing preen, circle flight, landing call, twig exchange, twig shake, crest raising, fluffed neck, bill clappering, bill duel, courting mount/false copulation[20], copulation[20]
Incubating	Adults sit on and rotate eggs to thermoregulate and protect them
Brooding	Attending to chicks, disposal of chick waste[20], molt/plumage grooming[20]
Feeding young	Feeding chicks or juveniles
Agonistic	Adult spreading-wing display, vertical display, forward display, bill duel, circle flight, supplanting, chick bullying/aggression/territoriality[20], siblicide[20]

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Alert behavior	Vigilant posture, hunkering, alarm calls, flying from the nest, wetlands or tree
Out of View	Heron leaves observers view

Scan and Focal Behavior Sampling

Scan and focal samples from the three observation points were completed in 2019 and 2020. In 2019, we collected data four to six days per week, from 31 March to 2 September, rotating observation time between the same three 5-hour periods. In 2020, data were collected approximately seven days a week (2 weeks of data collection were missed due to new implementation of COVID-19 protocols), from 15 March to 14 August, rotating between eight 2-hour time periods.

Scan Sampling. Scan samples quantified the percentage of time the group of herons spent doing a specific behavior and provided estimates of the average amount of time individuals within the colony conducted various behavior activities. Using a spotting scope we observed each bird in the colony and any individuals present in adjacent habitats. Every nest in the colony was uniquely numbered and a randomized number generator was used to select an occupied nest, then the scan began with the first heron the scope landed on in that nest. After recording the behavior of the first heron, we swiftly recorded the age, habitat and behavior of every heron in the colony and wetlands proceeding right to left until every heron's behavior had been recorded. After conducting a scan, we calculated the colony time budget by summing each individual

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exhibiting a specific behavior and dividing by the total number of herons included in the scan and converted these values to percentages.

Focal Sampling. In addition to scan sampling which quantified colony behavior, we used focal sampling to quantify heron behavior on an individual level. In this method, we randomly selected an individual heron, using a random generator application, from the colony or adjacent wetlands. In 2019, we observed and recorded a randomly selected heron every 30 seconds for 20 minutes and in 2020, to gain more resolution in behavior, we conducted 10-minute focal observations, recording the individual heron's behavior every 10 seconds. In 2020, we conducted 3 or more focal samples per sampling period and, as in 2019, we attempted to evenly survey heron age classes as well as sample herons in nests and wetlands within view. For every two nest samples, we conducted one wetland sample (when herons were present). A focal sample quantifies the percentage of time an individual heron spends doing specific behaviors. After conducting a focal sample, we calculated the focal time budget for that observation by summing each behavior category observed and dividing those by the total number of observations made in the set time frame. Averaging the individual focal time budgets for all the individuals in the colony provided a population time budget for the colony.

Temporal covariates. Both scan and focal samples included year, time of day, and breeding stage as covariates in statistical comparisons for 2019 and 2020. We grouped our samples of herons in daily time periods 0500-0700 (early morning), 0700-0900 (mid-morning), 0900-1100 (late morning), 1100-1300 (early afternoon), 1300-1500 (midafternoon), 1500-1700 (late

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afternoon), 1700-1900 (early evening), and 1900-2100 (late evening). We designated heron seasonal breeding stages with non-overlapping dates for analyses. The four heron breeding stages were nest selection and courting (15 March to 2 April), incubation (3 April to 1 May), hatching and brooding (2 May to 2 July), and fledging (3 July to 2 September). The beginning date for each heron breeding stage corresponds to the first observation date of that behavior and the end date corresponds to the date prior to observing the next main life cycle behavior (e.g., 3 April was the first observation of incubation and 2 May was the first observation of a chick hatching).

Age. We classified heron age as chick, juvenile, or adult. Chicks are pre-fledged young birds that still have down feathers and are in the process of developing flight feathers. They are nest residents, but as they approach fledge date they begin to wander and occupy adjacent nests or roost on tree canopy branches out of the nest. Juvenile herons have fledged, have well-developed flight feathers, and have reached adult size. These birds have left the nest, but still periodically are fed by parents and occasionally return to nests within a couple days of fledging. When we refer to young herons foraging and performing nest maintenance, these are chick and juvenile practicing these behaviors. Adults are 2-year or older breeding birds. Though age was recorded in the colony scans, it was not used as an independent variable in analyses at the colony scale because with scan sampling the percent time spent in each behavior was based on the sum of all the individuals in the colony and information associated with individual birds, such as age,

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could not be retained in a group metric. Age, however, was included in the individual behavior analyses.

Data Analyses

Behavior Analysis

We merged 2019 and 2020 scan and focal sampling data respectively to summarize the average time spent in behaviors across age classes for the individual data, and across the heron breeding stages and times of day for the colony data.

Tests for Independence

We tested for independence of behaviors and covariates using χ^2 tests. These tests examined the assumption that heron behaviors were independent across age classes, breeding stages, and times of day. Statistical significance between variables indicated an association between variables which may introduce bias or reveal a potential interaction.

Test for Statistical Differences in Behavior Frequencies

We used nonparametric Mann-Whitney U-tests (two sample comparisons) and Kruskal–Wallis H-tests (3 or more sample comparisons) to test for differences between the frequencies of behaviors across age classes, breeding stages, and times of day. For all significant Kruskal-Wallis tests, we used the nonparametric post-hoc Dunn's multiple comparisons test to determine which levels of the independent variable differed statistically. For all comparisons we used an alpha level of 0.05.

RESULTS

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Individual time budget comparison among age classes

Self-maintenance and posture ($H = 53.2$, $df = 2$, $p < 0.0001$), nest maintenance ($H = 23.2$, $df = 2$, $p < 0.0001$), locomotion ($H = 24.9$, $df = 2$, $p < 0.0001$), eating and foraging ($H = 11.2$, $df = 2$, $p = 0.003$), agonistic ($H = 11.9$, $df = 2$, $p = 0.0003$), thermoregulation ($H = 8.3$, $df = 2$, $p = 0.02$), and alert behaviors ($H = 6.6$, $df = 2$, $p = 0.04$) differed significantly by age class. Chicks spend the greatest percentage of their time performing self-maintenance or in a posture, as did juvenile and adult herons (Table 2). Though chicks spent a significantly greater percentage of time doing self-maintenance or in a posture (post-hoc Dunn test, $p < 0.0001$). Juveniles spent a significantly greater percentage of time foraging and eating (post-hoc Dunn test, $p = 0.003$) as well as thermoregulating (post-hoc Dunn test, $p = 0.02$). Adult herons spent over 50% of their time in a posture or performing self-maintenance, over 32% of their time incubating eggs, and over 7% of their time building and maintaining the nest.

Table 2. Average percent time spent in each behavior by great blue herons in 2019 and 2020 in relation to heron age at the Slate River Colony near Crested Butte, Colorado. Data from focal sampling.

Behavior Category **Sample size**	**Chick** **N=162**	**Juvenile** **N=119**	**Adult** **N=376**
Self- Maintenance and Posture	91.1	68.6	51.4

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Nest Maintenance	2.8	2.3	7.8
Locomotion	1.8	1.0	0.7
Foraging and Eating	1.2	4.4	2.2
Agnostic	1.1	0.5	0.3
Thermoregulation	0.2	1.5	0.5
Alert behavior	0.23	0.4	0.5
Out of View	1.6	21.4	1.2
Incubating	-	-	33.0
Brooding	-	-	0.9
Courtship	-	-	0.9
Feeding young	-	-	0.2
Total	**100.01**	**100.03**	**99.7**

Colony time budget comparison relative to seasonal stages

Self-maintenance and posture ($H = 69.9$, $df = 3$, $p < 0.0001$), nest maintenance ($H = 64.6$, $df = 3$, $p < 0.0001$), foraging and eating ($H = 12.5$, $df = 3$, $p = 0.006$), and agonistic ($H = 21.2$, $df = 3$, $p < 0.0001$) differed significantly by heron seasons. The months following spring arrival the colony spent a large proportion of their time building and maintain their nest site. This activity continues throughout the nesting season, but significantly decreases as the nesting season

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progresses (post-hoc Dunn test, $p < 0.0001$). The same trend was observed for colony courtship behaviors (post-hoc Dunn test, $p < 0.0001$). The heronry spent the greatest proportion of their time conducting self-maintenance and in postures during the early and late months of the nesting season (Table 3). These behaviors were lowest when eggs were laid when much of the colony's time was spent incubating. The frequency of colony incubation was greatest in the few months following the first initiation egg laying and decreased as eggs began to hatch. The colony's proportion of time spent foraging and eating was highest during the latest months of the breeding season.

Table 3. Average percent time spent in each behavior by great blue herons in 2019 and 2020 in relation to heron season. at the Slate River Colony near Crested Butte, Colorado. H is the Kruskal-Wallis non-parametric statistic, df = degrees of freedom, and p = probability (alpha = 0.05). Different superscripts indicate statistical significance while the same superscripts represent no statistical difference in results from post hoc Dunn tests (alpha = 0.05).

Behavior Category	**Nest Selection and Courtship**	**Incubation**	**Hatching and Brooding**	**Fledging**
Sample size	**N=26**	**N=90**	**N=197**	**N=177**
Self-Maintenance and Posture	73.0	40.9	55.4	78.7
Nest Maintenance	20.5	6.8	3.5	1.8
Courtship	3.7	2.3	0.5	0.03

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Locomotion	2.3	0.6	0.7	1.4
Thermoregulation	0.6	0.9	1.6	0.9
Foraging and Eating	0.0	0.3	1.4	2.8
Agonistic	0.0	0.1	0.9	1.1
Alert Behavior	0.0	0.2	0.04	0.1
Out of View	0.0	0.0	3.9	0.3
Incubation	-	48.0	30.3	12.4
Brooding	-	-	1.4	0.3
Feeding young	-	-	0.4	0.2
Total	**100.1**	**100.1**	**100.0**	**99.9**

Colony time budget comparison among times of day

Self-maintenance and posture ($H = 32.2$, $df = 7$, $p < 0.0001$), nest maintenance ($H = 29.1$, $df = 7$, $p < 0.0001$), thermoregulation ($H = 19.9$, $df = 7$, $p = 0.006$), and alert behaviors ($H = 30.3$, $df = 7$, $p < 0.0001$) differed significantly by time of day. The colony spent proportionally less time conducting self-maintenance or in postures during the late evening (post-hoc Dunn test, $p < 0.0001$). The colony did not spent any proportion of time performing courtship behaviors in the late evening (Table 4). Conversely, the colony spent proportionally more time incubating eggs in the late evening and proportionally less time incubating in the mid ($p = 0.03$) to late morning

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time periods (post-hoc Dunn test, p = 0.0004). We found the colony to spent the greatest percentage of time maintaining their nest in the mid-morning (post-hoc Dunn test, p = 0.0001).

Table 4. Average percent time spent in each behavior by great blue herons for 2019 and 2020 combined in relation to time of day at the Slate River Colony near Crested Butte, Colorado. EM = early morning to LE = late evening.

Behavior Category **Sample size**	**EM** N=43	**MM** N=50	**LM** N=84	**EA** N=72	**MA** N=92	**LA** N=100	**EE** N=49	**LE** N=13
Self-Maintenance and Posture	67.6	66.4	67.3	55.6	64.2	66.5	59.7	35.6
Incubating	24.6	18.3	20.5	30.8	26.5	25.1	25.4	47.3
Locomotion	1.6	0.4	1.4	1.1	0.8	1.2	1.0	2.9
Agonistic	1.1	0.9	1.3	0.5	0.3	0.7	1.4	0.4
Nest-Maintenance	1.0^{a}	7.5^{b}	4.9^{b}	5.6^{b}	2.4^{a}	4.4^{ab}	3.3^{ab}	4.9^{b}
Brooding	0.7	1.0	0.6	0.8	0.6	0.5	0.5	0.1
Out of View	0.7	1.9	0.6	1.5	1.3	1.7	3.8	6.7
Courtship	0.6	1.6	1.4	0.8	0.3	0.7	0.7	0.0
Foraging and Eating	2.0	1.5	0.9	1.6	0.9	2.5	2.0	1.7

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Feeding young	0.2	0.2	0.2	0.2	0.3	0.4	0.2	0.0
Thermoregulating	0.0	0.2	0.8	1.5	2.6	0.3	2.4	0.0
Alert Behavior	0.0	0.2	0.2	0.0	0.1	0.2	0.0	0.3
Total	**99.7**	**100.0**	**99.9**	**100.0**	**100.1**	**99.9**	**100.1**	**99.9**

DISCUSSION

The general finding of this study support the hypotheses that great blue heron behavior varies intrinsically and at temporal scales. These findings are supported by the vast literature on breeding great blue herons (Brandman 1976, Edford 1976, Stephens 1980). This study however, provides baseline behavior of a high elevation heronry that is undergoing land use level changes and could potentially be impacted by global changing weather patterns. Thus these finding may serve as guidelines for future management and conservation.

Age was a major intrinsic factor that predicted heron behavior. Adult herons spent half of their time at the nest resting (in a posture) or conducting self-maintenance activities (preening). The other main activities at the nest included nest maintenance and incubation, both behaviors are vital for reproductive success. Once the young hatched, adults spent time more time brooding and foraging. Young nestling spent greater than 90% of their time resting or conducting self-maintenance. Chicks practiced nest maintenance by grabbing sticks in the nest and wiggling them. The literature currently lacks detailed documentation on great blue heron chick behavior,

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but this behavior might also be associated with the prey striking strategy great blue herons utilize to forage. Once young nestlings doubled in size and began to develop feather for flight we observed more frequent feeding events by parents. Newly fledged herons utilized the nearby wetlands to practice foraging and frequently went out of the observers view.

Colony behavior shifted during the stages of the breeding cycle. From mid-March to the beginning of May adult herons at the colony are forming pair bonds and building their nests. This is a vital time for the mostly solitary birds to bond and begin securing a nest to raise their brood of one to four chicks. In a heavy snow year the area around the colony has limited foraging and for this reason we did not observe adult foraging near the vicinity of the colony from the first arrival until early May. Once eggs had been laid, one adult spent much of their time incubating while the other foraged. At this time snow melt has made pristine foraging conditions in the wetland areas surrounding the colony, thus providing and energetic advantage to the birds (Pratt 1970). As chicks begin to hatch an adult spent time at the nest brooding the young. Chicks rapidly grew as their parents frequently delivered food to their brood. The enlarging chicks fought for space in the nest and over food regurgitated by their parents.

The Slate River heron colony did not show a distinct diel pattern of behavior. The literature suggests coastal heron behavior is aligned with the tides, while inland heron behavior follows a diel pattern with feeding the young showing peaks in the morning and early evening (Ferguson and Elkie 2004, Birkett et al 2012). This colonies greatest time spent feeding young was in the midafternoon (1300-1500) and late afternoon (1500-1700). The colonies time spent

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thermoregulating correlated to the hottest time of day (midafternoon, 1300-1500) and another spike before sun to set (early evening, 1700-1900) when herons were observed sun bathing. Heron spent the greatest amount of time incubating when the sun was setting and temperatures began to drop (late evening, 1900-2100).

Management Implications

Our age class, seasonal, and daily time budgets of individual and colony samples provides a baseline to gauge possible impacts of land use changes, changing weather patterns, and changes in human use in the Slate River Valley. The Slate River Valley provides a unique combination of environmental characteristics including the adjacency of nesting and foraging areas in undisturbed landscapes. Locations such like this are becoming a rarity as the United States Canada has lost nearly 85% of their wetland habitats (Dahl 1990, National Research Council 1995). Remaining wetland sites, such as the Slate River Valley, are vital for reproductive success of waterbirds like the great blue heron (Rosenberg et al 1991, Davis and Ogden 1994, DeGraff and Rappole 1995) and the close proximity of foraging sites to the nests provide and energetic advantage to a colony (Gibbs and Kinkel 1997). The adults lives are tied to the nest for five to six months of the year and they must utilize their local environment to fulfill their nutritional and energetic needs as well as those of their brood of one to four chicks (Pratt 1970). The chicks are nest bound for the first four months of life and require relatively undisturbed conditions for survival (Werschkul, D. F., McMahon, E., and Leitschuh, M. 1976). Due to the

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colonial nesting nature of great blue herons, a significant proportion of the regional population is vulnerable if the site is disturbed by human activity or is altered by changing weather patterns. It has been established that mountain systems are more vulnerable to climate change than lower elevation sites (Diaz et al 2003). That is why it is pertinent that the impacts of increasing temperatures on snowfall, snowpack, and on subsequent river flows is studied in detailed. Alterations to weather and waterflow patterns could have drastic impacts to annual foraging habitats required for breeding heronries (Grau and Parris 1980). Mountain systems may also experience extreme weather events as climate change repercussions worsen (Cottrille and Cottrille 1958). Breeding herons are especially vulnerable in their treetop nests; big wind gusts, intense rain and hail events, as well as lighten can be problematic. Further documentation of heron behavior and habitat use are needed to understand the potential vulnerabilities of climate change at this high elevation site.

Mountain communities are also popular tourist locations and Crested Butte, CO has a thriving tourist economy with a growing demand for outdoor recreation (Lieberman 2016). The upper Slate River heron colony is faced with human encroachment into their breeding site as the demand for river recreation increases. River floaters are a major stress inducing recreation activity this heronry faces due to the river flowing directly under the nests. To minimize heron disturbance in the face of human recreation, spatial buffers and temporal restrictions are often employed for heron conservation (Vos et al 1982, Butler 1991, Carlson and McLean 1996, Gebauer and Moul 2001). A disturbance free environment is beneficial through hatching and the

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early brood guardian phase (Quinney 1982, Vos et al 1985, Butler 1991). Limiting disturbance, especially early in the nesting season, may reduce the likelihood of colony abandonment and increase the likelihood of chick survival (Fremming 1980, Traut and Hostetler 2003). The Slate River heron colony spent less than 1% of their time under normal conditions in alter posture or in other disturbance behaviors. These herons spent 50-90% of their time resting or conducting self-maintenance activities (low energy). An event, such as river recreation can led to herons being flushed or they become vigilant which are more costly behaviors. In some cases human events interrupt foraging bouts, which can extend the length of time to catch prey or even cause herons to lose the opportunity to secure prey. Although the Great Blue Heron is not an at-risk species, it is an indicator species and can be used to monitor landscape level changes (Kushlan 1993, Erwin and Custer 1982). Due to being at the top of the aquatic food chain and having a fixed breeding site, this species is first in line to exhibit vulnerabilities to changing weather patterns and increased human presence.

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APPENDIX A. SUPPORTING INFORMATION

Figure A4. The Slate River heronry from the vantage of Smith Hill Road to the east. The main current of the Slate River is traced in dark blue and flows from right to left in the photo. The

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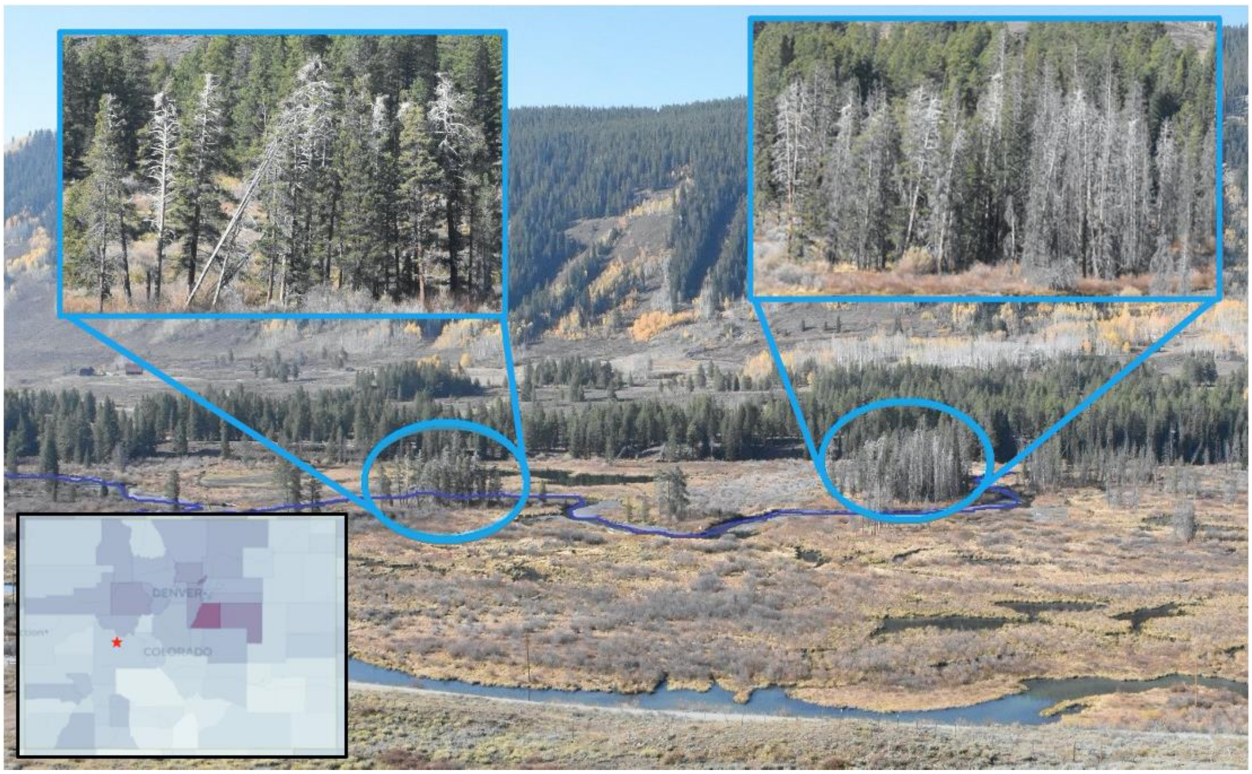
upper (on right) and lower (on left) sub colonies are circled in light blue and are separated by roughly 128 m. The inset photographs, outlined in light blue, show up-close images of the sub colonies. The inset map of Colorado shows the location of Crested Butte with a red star. Photos were taken 7 October 2020 by Alex Stogsdill.



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