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Research Article

Cliff-Dwelling Bird Species Show Variable Behavioral Responses to Rock Climbing

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ABSTRACT

Cliff environments have historically been relatively undisturbed, but growth in the popularity of rock climbing is changing this pattern. As land managers face increasing pressure to open new rock climbing areas, there is a need to understand the potential impacts of human presence on cliffs. To that end, we examined how rock climbing activity affects the occurrence and behavior of passerine birds, with a focus on the behaviors of four cliff-specialist bird species at high- and low-use climbing sites. We found that rock climbing use level did not affect the occurrence or behavior of white-throated swifts (*Aeronautes saxatalis*). Violet-green swallows (*Tachycineta thalassina*) showed small behavioral changes and were frequently observed at high-use climbing sites, suggesting an attraction to humans. In contrast, the behavioral patterns, but not occurrence rates, of common ravens (*Corvus corax*) and canyon wrens (*Catherpes mexicanus*) were affected by rock climbing site use. In particular, canyon wrens engaged in a greater diversity of behaviors at low-use climbing sites, with reduced foraging and singing at high-use climbing sites. Results indicate that avian species are differentially affected by rock climbing, with white-throated swifts and violet-green swallows coexisting well with climbers. Canyon wrens showed the strongest responses to rock climbing, making them a species of concern and a target for protection because they are cliff-dependent and experiencing population declines. We recommend including behavioral observations when monitoring specialist species, so that such data can inform management relating to recreation at cliff areas.

Index terms: birds; *Catherpes mexicanus*; cliff ecosystems; recreation ecology; rock climbing

INTRODUCTION

As human recreation increases in natural environments, there is a growing need to balance demands for human access with habitat protection (Leung and Marion 2000). Numerous studies have reported negative impacts of recreation on wildlife (Boyle and Samson 1985; Papouchis et al. 2001; Taylor and Knight 2003; Schmera et al. 2018), and additional research has documented recreation as a specific threat to birds (Steidl and Anthony 2000; Heil et al. 2006; Wolf et al. 2013; Rösner et al. 2014; Thompson 2015). Recreation may affect wildlife either indirectly, through habitat modification, or directly, through disruption of normal behavior, and can have both short- and long-term consequences (Camp and Knight 1998a; Beale and Monaghan 2004).

The recent increase in the popularity of rock climbing represents a growing disturbance to cliff ecosystems, an important and understudied avian habitat (Krajick 1999). From 1991 to 2001, the number of climbers in the United States increased from 100,000 to 400,000 (Schuster et al. 2001) and it has continued to rapidly rise (Outdoor Industry Association 2017). Climbers can directly impact cliffs and organisms that rely on cliff habitat in multiple ways, such as through trampling and rope abrasion of vegetation, displacing animals, and modifying rock substrate (Camp and Knight 1998a, 1998b; Krajick 1999; Adams and Zaniewski 2012). Climbers commonly remove plants, lichens, loose rock, and soil initially found on climbing routes to provide more secure hand and footholds (Krajick 1999; McMillan and Larson 2002). These habitat modifications and the presence of climbers can disrupt nesting birds (Brambilla et al. 2004) and alter other wildlife activity (Camp and Knight 1998a; Loeb and Jodice 2018). Because cliffs typically make up a small portion of a landscape and cannot be created or restored, cliff-specialist birds may be particularly vulnerable to habitat change and disturbance.

Cliffs have considerable conservation value, as they often support high levels of biodiversity (Ward and Anderson 1988; Camp and Knight 1998a, 1998b; Krajick 1999; McMillan et al. 2003), harbor glacial relics (Wezel 2007; Adams and Zaniewski 2012), increase habitat heterogeneity, concentrate resources (Krajick 1999), offer a wide variety of niches (Krajick 1999), and support unique species and assemblages of species, including birds (Camp and Knight 1998a). Although the impacts of rock climbing on vegetation are well documented (Nuzzo 1996; Farris 1998; McMillan and Larson 2002; Kuntz and Larson 2006; Adams and Zaniewski 2012), relatively few studies have investigated the effects of disturbance on the behavior of cliff-using birds. Among those that assessed disturbance, the focus was generally on reporting observations of either raptors or colonial seabirds, with limited studies on passerines (Larson et al. 2000). Studies that have examined entire avian communities on cliffs have generally found that climbing reduces avian cliff use and diversity (Camp and Knight 1998a; Covy et al. 2019) but questions remain about impacts on individual activity.

Many birds that use cliffs are highly specialized and rely on this habitat type, although others show flexibility in choosing their nesting substrates (Larson et al. 2000). Human presence

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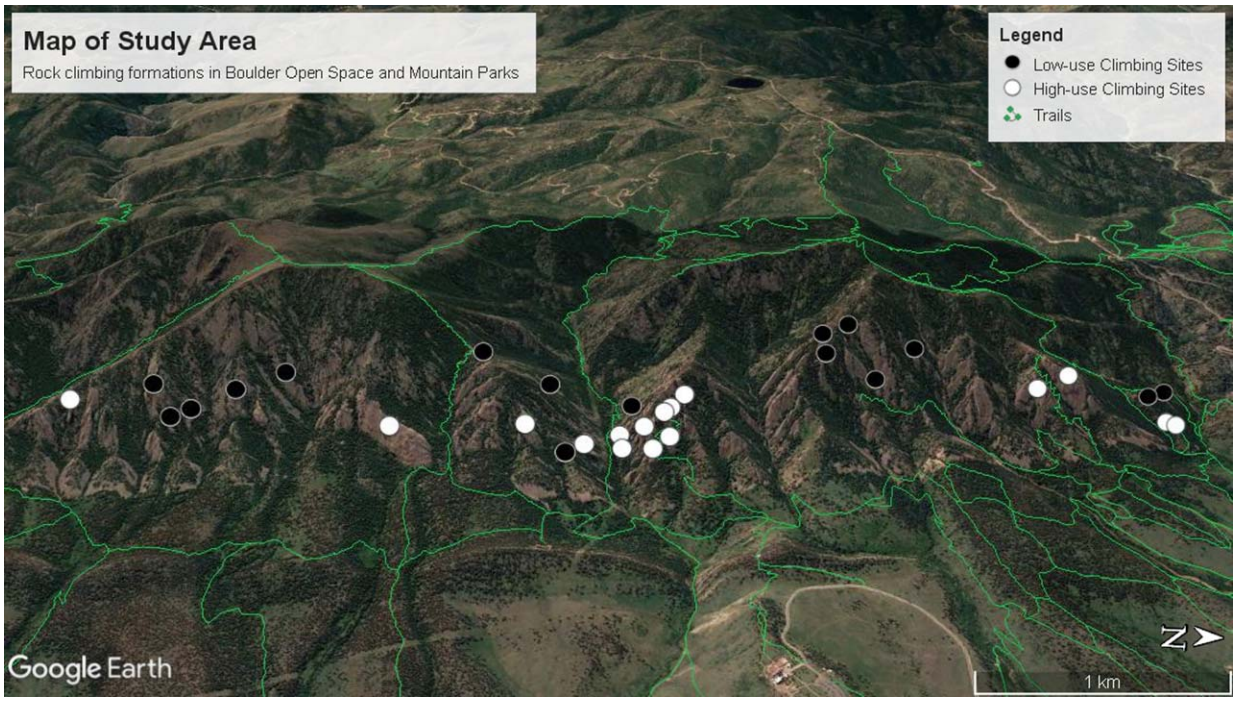

Figure 1.—Map of the study area within Boulder Open Space and Mountain Parks where we evaluated avian behavior at cliffs that vary in rock climbing use. Sites are west of the City of Boulder, Colorado, USA. Map image data from Google Imagery and Terra Metrics, reprinted under the Google Earth usage permission policies (https://www.google.com/permissions/geoguidelines/).

near cliffs has the potential to disturb specialized bird species, thereby reducing the amount of time that an individual bird might spend foraging, incubating, resting, or performing other behaviors, and such disturbances may lead to abandonment of broods or territories, or reduce productivity (Knight and Swaddle 2007; Attarian and Keith 2008; Steenhof et al. 2014). Thus, avian activity budgets may provide evidence of disruptions to activities that could decrease fitness (Camp and Knight 1998a, 1998b; Steidl and Anthony 2000; Beale and Monaghan 2004; Arlettaz et al. 2015). Tolerance of human presence by birds varies among species and habitats, making it important to assess human impacts for a variety of locations, species, and habitat types, including cliffs (Heil et al. 2006).

We examined how rock climbing influenced the occurrence and behavior of avian species at cliff formations in City of Boulder Open Space and Mountain Parks (OSMP), Colorado, USA. Boulder OSMP includes multiple popular climbing sites (Haas 2009; Holzman 2013), and visitation rates increased 33% from 2005 to 2017 (Leslie 2018; VanderWoude and Kellogg 2018). Similar to other land management agencies, OSMP operates under a dual purpose mandate of protecting habitat and providing recreational opportunities. Therefore, empirical studies that investigate this relationship are beneficial in implementing responsive habitat management strategies. Birds in this community use the cliffs even when climbing is frequent but the effects of climbing on the behavior of cliff-dependent species are unknown (Covy et al. 2019). To investigate this topic, we studied avian activity budgets in low- and high-use climbing areas on OSMP. We predicted that birds would occur at greater rates and would allot more time to a greater variety of behaviors at low-use climbing areas.

METHODS

Study Area

Boulder Open Space and Mountain Parks consists of about 19,000 ha located in the foothills and plains surrounding the city of Boulder, Colorado. The park receives over 6 million visitors annually (Leslie 2018). We focused on a 5 km stretch within OSMP near N39.995828°, W105.295606° (Figure 1). This area falls within the Lower Montane Zone and has an elevation ranging from 1800 to 2300 m above sea level. Cliffs in the area are embedded in ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) forest habitats (see Covy et al. 2019 for more detail).

Study Species

We chose to study four species of cliff-obligate birds in OSMP—white-throated swift (*Aeronautes saxatalis*), violet-green swallow (*Tachycineta thalassina*), canyon wren (*Catherpes mexicanus*), and common raven (*Corvus corax*)—because of their abundance and potential differences in behaviors near humans (Rossi and Knight 2006; Covy et al. 2019). Due to the difficulty of accessing their nesting locations, basic information on the use of cliff habitat, behavior, and productivity of these species is limited (Jones and Dieni 2020; Ryan and Collins 2020). White-throated swifts and violet-green swallows are aerial insectivores that spend much of their time flying and use cliffs primarily for nesting or roosting (Brown et al. 2020; Ryan and Collins 2020). Canyon wrens use cliffs for nesting, roosting, and foraging, and are highly dependent on this habitat (Jones and Dieni 2020). They are often seen navigating cracks and crevices of cliffs and talus slopes (NC, pers. obs.). Canyon wren populations are declining in Colorado and range-wide (Pardieck

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et al. 2019), making this a particularly interesting species for which to investigate behavioral effects of human use of the landscape. Unlike canyon wrens, common ravens are increasing in western North America, and this species is sometimes considered a human commensal (Boarman and Heinrich 2020).

Data Collection

We conducted 182 surveys of birds at 16 high-use and 16 low-use climbing formations (Figure 1) between 10 May 2015 and 24 July 2015 (Covy et al. 2019). High-use sites were visited by over 500 climbers per year, while low-use sites were visited by fewer than 100 climbers per year (OSMP unpub. data). Each low-use climbing site was paired with a high-use site in relatively close proximity (within 1.5 km) that had a similar aspect, verticality, and height (see Covy et al. 2019 for more detail). Site pairs were surveyed on consecutive days, and over the course of the study each pair was surveyed five or six times: twice in the morning (within 3 hr post-sunrise), twice during midday (10:30–13:30), and once or twice in the afternoon (within 3 hr pre-sunset). Surveyors sat 20 m from the base of the cliff and recorded avian activity on and around a 30 m wide section of cliff face for 1 hr (Covy et al. 2019). At 1 min intervals, surveyors recorded the bird species present and whether they observed each of the following seven behaviors during a 30 sec period: perching, flying, hopping, foraging, calling, singing, visiting nest. Therefore, each survey consisted of 60 scans and an active survey time of 30 min. Surveyors also recorded the number of people present at the site.

We calculated the activity budgets for all species we observed during at least 20 surveys and 100 scans within those surveys. This included four species: white-throated swifts, violet-green swallows, canyon wrens, and common ravens. We quantified occurrence as the number of scans per survey in which birds of that species were observed. We compared avian occurrence between high- and low-use climbing sites by comparing the mean number of scans with occurrence per survey for a given species. Because we had a sample size of 32 and some sites had no activity, this comparison was conducted using a nonparametric Wilcoxon rank-sum test. We analyzed avian behavior and compared activity budgets between high- and low-use climbing sites by conducting Pearson's chi-squared tests, which compared the total number of scans in which a particular species was observed engaging in each activity at the high- and low-use sites.

We identified nest sites based on behavior of adults (e.g., repeated visits to a specific crevice) or when nestlings could be heard later in the season. Because we could not always confirm the presences of nestlings, we refer to these as putative nest locations hereafter. We included fledgling behavior in our analysis. All statistics were run in JMP 9.0 and 13.0 (https://www.jmp.com/). We considered results statistically significant when $P \leq 0.05$ and report metrics as mean (±SE).

RESULTS

We observed 45 bird species in our survey areas, with 37 species observed at high-use climbing sites and 39 species observed at low-use climbing sites (for more detail, see Covy et al. 2019). We observed climbers on the cliffs in 7% ($n = 12$) of surveys, for a total of 35 climbers at high-use sites and three climbers at low-use sites. Because we did not observe climbers during most surveys, differences in avian behavior between climbing use categories should be interpreted mainly as responses to long-term patterns of human presence rather than as reactions to immediate disturbance. When climbers were present within the survey area, on average there were 3.2 people and they were present for 25.8 min. We noted variability in avian behavior, but did not observe any obvious direct responses to the climbers or consistent trends in behavior while climbers were present.

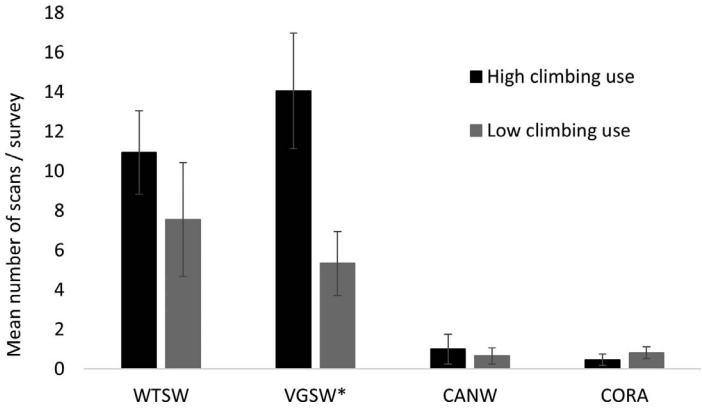

Figure 2.—Mean (±SE) number of scans per survey during which four avian species, canyon wren (CANW), violet-green swallow (VGSW), white-throated swift (WTSW), and common raven (CORA), were observed at cliffs that receive high and low numbers of rock climbers near Boulder, Colorado, USA, in 2015. Asterisks indicate significant differences between high- and low-use climbing sites at $P < 0.05$.

We found putative nest sites at both high- and low-use climbing sites, with more present at high-use sites. We identified two putative nest sites of violet-green swallows at low-use climbing formations and seven at high-use climbing formations. We identified three putative nest sites of white-throated swifts at low-use climbing formations and 11 at high-use climbing formations. Birds were still observed visiting nests during some surveys when climbers were present.

White-throated swifts and violet-green swallows were most commonly observed at our survey sites, and both species nested within the observation areas. Individuals of these species were present during 62% ($n = 114$) and 68% ($n = 125$) of the surveys, respectively. We observed violet-green swallows at all 32 sites, and white-throated swifts at all high-use climbing sites plus 15 of 16 low-use sites. We observed violet-green swallows during more scans per survey (i.e., higher occurrence rates) at high-use climbing sites ($\chi^2 = 7.67$, $P = 0.006$; Figure 2). Although the apparent mean occurrence rate of white-throated swifts was also greater at high-use sites (Figure 2), the difference was not statistically significant ($\chi^2 = 2.76$, $P = 0.097$).

White-throated swifts and violet-green swallows spent large portions of their time flying, calling, and visiting nests (Figure 3). Violet-green swallows perched and sang occasionally. White-throated swifts generally did not perch on cliff faces. There was no difference in activity budgets between high- and low-use climbing areas for white-throated swifts ($\chi^2 = 3.11$, $P = 0.37$; Figure 3). However, violet-green swallows visited nests more at

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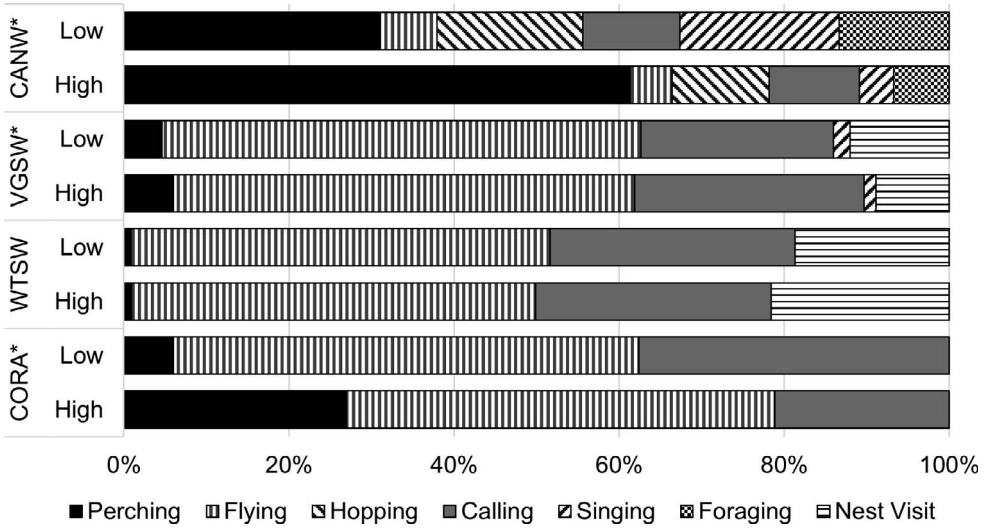

Figure 3.—Summary of activity budgets for avian cliff specialists, canyon wren (CANW), violet-green swallow (VGSW), white-throated swift (WTSW), and common raven (CORA), at high- and low-use climbing areas near Boulder, Colorado, USA, in 2015. Asterisks indicate significant differences between high- and low-use climbing sites at $P < 0.05$.

low-use sites and called more at high-use sites ($\chi^2 = 12.44$, $P = 0.014$; Figure 3).

We observed canyon wrens during 12% of surveys ($n = 182$); they were observed during the same number of scans at high- and low-use climbing sites ($\chi^2 = 0.073$, $P = 0.79$; Figure 2). Canyon wrens were the only species we observed foraging (Figure 3). On two occasions (once at a high-use site and once at a low-use site), we observed fledglings accompanied by adults. The activity budgets of canyon wrens differed between high- and low-use climbing sites ($\chi^2 = 33.00$, $P < 0.001$; Figure 3). Canyon wrens spent more time perching and less time foraging and singing at high-use climbing sites (Figure 3). We did not locate any canyon wren nests within our survey areas.

We observed common ravens during 22% ($n = 40$) of surveys, with no difference in occurrence rate between climbing use categories ($\chi^2 = 1.69$, $P = 0.19$; Figure 2). Common ravens exhibited flying, calling, and perching behaviors during surveys. They spent proportionally more time perching and less time calling at high-use climbing sites than at low-use climbing sites ($\chi^2 = 15.83$, $P = 0.0004$; Figure 3).

DISCUSSION

Contrary to our prediction, we found no relationship between avian occurrence rate and rock climbing for any of our study species except violet-green swallows, which occurred at a greater rate at high-use climbing sites. Thus, we have no evidence that rock climbing reduces cliff use by these four cliff-dwelling species. However, as we predicted, activity budgets of three of four species differed between climbing-use categories. At low-use sites, violet-green swallows spent more time visiting nests, canyon wrens foraged and sang more often, and common ravens called more. At high-use sites, violet-green swallows called more, and canyon wrens and common ravens spent more time perching.

Why might violet-green swallows occur more often at high-use climbing sites? Attributes of the cliffs themselves could be the cause of differential activity, but our paired design controlled for effects of cliff height, aspect, angle, rock substrate, and elevation (Tessler and Clark 2016). Therefore, our results suggest that there may be a benefit of associating with climbers for this species. Violet-green swallows may be more tolerant of human presence than other species, as they are considered suburban adaptable (Blair 1996) and occasionally nest in artificial structures (Brown et al. 2020). Association with humans in urban environments likely occurs because this species exploits artificial cliff-like substrates, such as building ledges, but this advantage is not available on cliffs at climbing sites. Why then were they present in higher numbers at high-use climbing sites? High-use climbing sites may harbor more cracks and crevices that birds prefer as nesting habitat and climbers prefer as handholds. A second possibility is that a predator refuge effect is occurring whereby some species associate with human presence to avoid predators that are wary of humans (Berger 2007; Muhly et al. 2011). In support of this possibility, prairie falcons (*Falco mexicanus*) and peregrine falcons (*Falco peregrinus*), which nest in our study area and prey on aerial-foraging birds, were observed at 33% more low-use climbing sites than high-use climbing sites (Covy et al. 2019).

Although violet-green swallows did not avoid climbing areas, we found evidence that human use may impact their behavior. They spent more time visiting nests in low-use sites even though we suspected there to be two times more nests at high-use sites. Thus, patterns of nest attendance and nest site selection may be differentially impacted by human presence. The differences in nest visitation and calling rates were relatively small between high- and low-use climbing sites; future studies could investigate potential fitness consequences of these differences. Overall, the occurrence patterns paired with small behavioral changes suggest that rock climbers do not have strong negative impacts on violet-green swallows.

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Interestingly, the occurrence pattern and activity budget of the other aerial insectivore—white-throated swift—did not differ between high-use and low-use climbing sites. Individuals occurred, flew, called, perched, and visited nests equally at cliffs in both climbing use categories. This is contrary to our prediction that climbers disrupt natural behavior patterns of this species. Previous studies have found results similar to ours: white-throated swifts in British Columbia and Joshua Tree National Park are known to nest on cliffs used for rock climbing (Camp and Knight 1998a; Richardson 2000). Like violet-green swallows, these aerial insectivores appear to do well in the presence of humans.

Common ravens were regularly observed at our study sites and showed different behavior patterns between site-use categories. Unlike Camp and Knight (1998a), who observed common ravens more often at unclimbed cliffs than popular climbing cliffs, we found common raven occurrence to be similar at high- and low-use climbing sites. Additionally, we observed common ravens perching more and vocalizing less at more frequently climbed cliffs. Common ravens were locally abundant in our study area, and their populations are increasing in the western United States (Boarman and Heinrich 2020). Therefore, although they show altered behavior with climbing activity, general population trends make them a relatively low concern for land managers trying to prevent avian population declines.

Although canyon wren occurrence was not impacted by climbing, our observations of canyon wren behavior supported our prediction of behavioral disruption. Canyon wrens performed all the same behaviors (singing, calling, foraging, perching, hopping, and flying) at both high- and low-use climbing sites, but spent proportionally more time perching and less time foraging, hopping, and singing at high-use sites. Our results suggest that increased levels of rock climbing impact canyon wren behavior. Reduced time spent foraging and communicating can result in decreased individual fitness (Steidl and Anthony 2000; Beale and Monaghan 2004; Knight and Swaddle 2007; Arlettaz et al. 2015). Singing is important for canyon wren males in establishing and defending breeding territories (Benedict et al. 2012, 2013). Therefore, reduced vocalizations could decrease resource holding potential (Krebs 1977; Yasukawa 1981). Additionally, unlike our other study species, canyon wrens rely heavily on cliff crevices for foraging, so human activity on cliffs could decrease foraging opportunities (Warning and Benedict 2015; Warning and Leatherman 2016).

Canyon wrens near our study area do not occupy all available habitat (Jones et al. 2002; Warning et al. 2015). The abundance of suitable habitat and low density of this species may allow them to select cliffs with minimal climbing disturbance, but our data did not support this possibility, as canyon wren occurrence was similar at high- and low-use climbing sites. Therefore, increased recreation levels and new climbing routes have the potential to disrupt nesting canyon wrens occupying preferred habitat, either through human presence itself, or via human-caused modifications of cliff habitat made during route cleaning. Canyon wrens nest at varying heights on cliffs as well as in smaller outcrops or piles of rocks (Jones et al. 2002). Climbers may impact the species directly if they damage nests while climbing as has been previously documented (Jones et al. 2002). Small mammal, snake, and corvid predators, which either tolerate or thrive in areas of human disturbance (Miller et al. 1998), may also have increased access to canyon wren nests in disturbed areas. Given that canyon wren populations are declining throughout their range (Pardieck et al. 2019), human-caused disruptions of natural behavior patterns or nesting attempts should be avoided to conserve this sensitive species (Jones and Dieni 2020).

In summary, we did not find that our focal species avoided cliffs that are more frequently used by rock climbers, but some birds did show behavioral disruptions with climbing. White-throated swifts and violet-green swallows were frequently observed and showed a natural range of behaviors, including nesting, at high-use climbing use sites. This suggests either that these sites offer some type of habitat advantage or that some species are attracted to human presence. We recommend monitoring these species to assess population stability, but foresee limited impacts to them as land managers open new climbing areas. In contrast, common ravens and canyon wrens were less frequently observed, and altered their behavior with increased human use of cliff habitat. Increasing population trends in common ravens and decreasing population trends in canyon wrens make this finding of greater concern for the latter species. The proportion of time that canyon wrens spent singing and foraging was lower at high-use climbing sites, perhaps indicating that rock climbing has negative fitness consequences for this species. Because canyon wren life history and population trends are poorly understood (Jones and Dieni 2020), further research on nest site selection would benefit managers tasked with overseeing cliff habitats, managing placement and use of recreational trails, and developing habitat conservation measures. Our study demonstrated that occurrence of a species alone does not provide a complete picture of the effects of anthropogenic disturbance. Accordingly, we recommend that land managers include analyses of animal behavior when examining ecosystem health and develop avenues to educate climbers and other park visitors about the conservation value and uniqueness of cliff habitats.

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Nora Covy completed her MS in Biological Sciences at the University of Northern Colorado. She enjoys using GIS to address

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conservation issues and is currently working with geospatial data to monitor water system quality and assist with leak detection efforts.

Will Keeley is a wildlife ecologist with the City of Boulder Open Space and Mountain Parks Department. His research interests include raptor ecology, the dynamic between humans and wildlife, and the benefits of habitat restoration.

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