METHODS, TRANSLOCATIONS AND REINTRODUCTIONS, AND HABITAT USE

Evaluating Citizen Science Mountain Goat Counts Using GPS-Collared Goats in Southwest Montana

JULIE CUNNINGHAM, *Montana Fish, Wildlife and Parks, Bozeman MT, 59718, USA; juliecunningham@mt.gov*
KELLY PROFFITT, *Montana Fish, Wildlife and Parks, Bozeman MT, 59718, USA*

ABSTRACT: Accurate wildlife population counts inform sustainable harvest management. This is particularly important for mountain goats as they are challenging to count and susceptible to over-harvest. We evaluated a citizen-science ground counting method paired with 14 GPS collared animals to obtain minimum counts and population estimates for mountain goats in the Bridger Mountains, southwest Montana. During 2021–2023, the Rocky Mountain Goat Alliance and Montana Fish, Wildlife and Parks (MFWP) partnered to perform 3 ground-based surveys. Surveys occurred by strategically posting citizen volunteers at the same day and time throughout goat habitat within the mountain range. We processed survey data using an algorithm considering time, location, and group composition to eliminate duplicate observations. Treating collared animals as marked and resighted animals as recaptured, we estimated annual population sizes using Peterson (Chapman–corrected) mark-recapture estimators. Minimum mountain goat counts were 28 in 2021 (a year when smoke from wildfires impeded visibility), 93 in 2022, and 103 in 2023. Observers detected 2 of 10 collared goats (20%) in 2021, 10 of 13 collared goats (77%) in 2022 and 10 of 12 of collared goats (83%) in 2023. Peterson mark-recapture estimates of the total population in 2021, 2022, and 2023 were 102 (approximate 95% confidence interval 19-184), 119 (approximate 95% confidence interval 89–149), and 122 (approximate 95% confidence interval 96–148). High recapture rates (when smoke did not impede visibility) and similarities of ground counts with mark-recapture estimates suggested that citizen-science ground counts were a replicable and informative means to inform mountain goat management in this study area.

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KEYWORDS: Bridger Mountains, citizen science, GPS collar, ground survey, mark-recapture, Montana, mountain goat (*Oreamnos americanus),* Peterson (Chapman-corrected) mark-recapture estimator.

Obtaining accurate survey data to inform wildlife management is key for wildlife biologists (Leopold 1933, Lancia et al. 1996). Mountain goats (*Oreamnos americanus*) are notoriously difficult to count due to their remote and rugged habitats (Chadwick 1983, Rice et al. 2009) and they are also a species which can be susceptible to overharvest (Festa-Bianchet and Côté 2008). In Montana, wildlife biologists use multiple tools to obtain minimum counts from which they recommend hunting license numbers and harvest rates (DeCesare and Smith 2019). Biologists use helicopters, fixed-wing aircraft, and ground surveys during winter, early spring, mid-summer, late-summer, and fall months, sometimes with several years between surveys (DeCesare and Smith 2019).

Ground-based methods have shown promise for counting and estimating mountain goat populations in some areas where using biologists or trained citizen scientists could produce useful data (Belt and Krausman 2012, DeVoe et al. 2015, Flesh and Belt 2017). In other areas, ground counts returned lower population counts than aerial surveys but nonetheless were an economically efficient method of obtaining important information and providing community education and awareness (Reynolds et al. 2022).

Montana Fish, Wildlife and Parks (MFWP) used aerial surveillance (helicopter and fixed-wing aircraft) to count mountain goats in the Bridger Mountains from 1978 to 2016, during which time the highest count recorded was 74 goats in 2002. In 2017 and 2019, MFWP and the Rocky Mountain Goat Alliance (RMGA) conducted two citizen science ground-based surveys in the Bridger Mountains, resulting in counts of 79 and 127 mountain goats. These results suggested ground-

based surveys could be an effective method for obtaining minimum mountain goat counts in the Bridger Mountains. Building from these efforts, our objective was to employ mark-recapture methods using radio-collared mountain goats (2021–2023) to provide insights regarding the effectiveness of citizen science ground-counts to estimate mountain goat sightability and population size.

STUDY AREA

The study area was Bridger Mountain Range north of Bozeman, Montana (approximately 45.90°N, -110.98°W; Figure 1). The Bridger Mountains run north to south and are approximately 40km long and 8–10km wide. The mountains are bordered by rolling forested foothills to the east and a sharp transition to grassy foothills on the western front. Elevations range from 1,800m in the foothills to 2,946m at the highest peak. Depending on elevation and aspect, forest communities can include Rocky Mountain juniper (Juniperus scopulorum), Douglas fir (Pseudotsuga menziesii), lodgepole pine (Pinus contorta), Engelmann's spruce (Picea englemanii), limber pine (Pinus flexilis), and subalpine fir (Abies lasiocarpa). Understories include a substantial non-native component with timothy grass (Phleum pratense) and sweet clover (Melilotus spp.) noted even at high elevation. Tree line is approximately 2,400m. The area is considered a dry mountain range with mean annual precipitation of 51cm (USDA 2012), and only 4 lakes, 3 of which may be ephemeral.

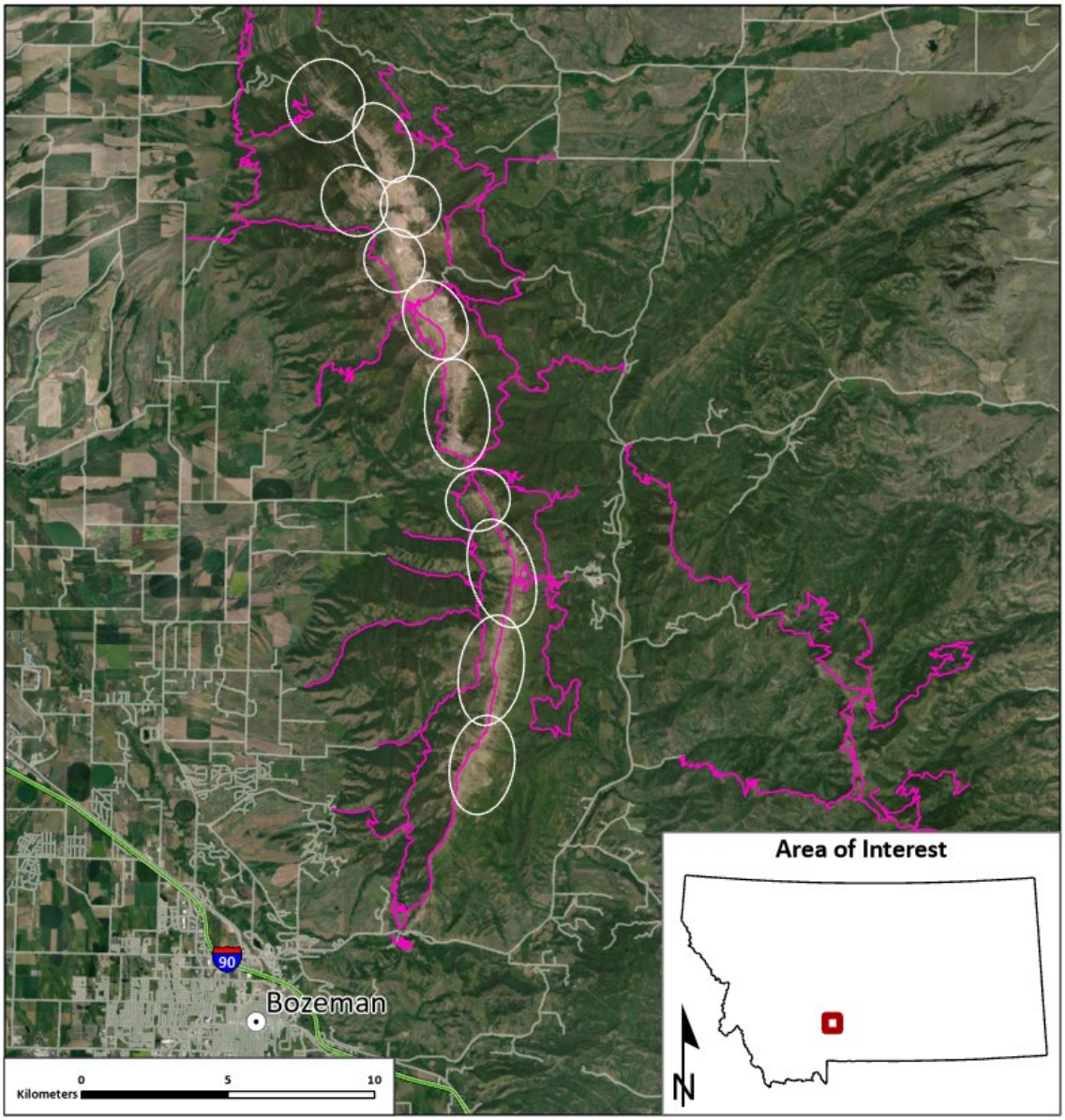

Figure 1. Bridger Mountains, southwest Montana, trails (pink) and ground survey observation areas (white ellipses).

Mountain goats were introduced to the Bridger Mountains in 1969 from a founding population of 13 individuals. Their population appears to be thriving despite significant human recreational use across their habitat (Macdonald et al. *in review*, MFWP unpublished data). A network of >190km of designated USFS trails exists in the approximately 80km^2 of known mountain goat distribution (Figure 2). Goat habitat selection models indicated mountain goats avoid tree cover in this area (Macdonald et al. *in review*). Mountain goat distribution is almost exclusively on U.S. Forest Service lands. Mountain goats are accessible to hunters and grow to trophy size, making the 5 hunting licenses issued annually among the most prized hunting opportunities in Montana. Mountain goats also provide viewing opportunities to Bozeman's burgeoning recreational community.

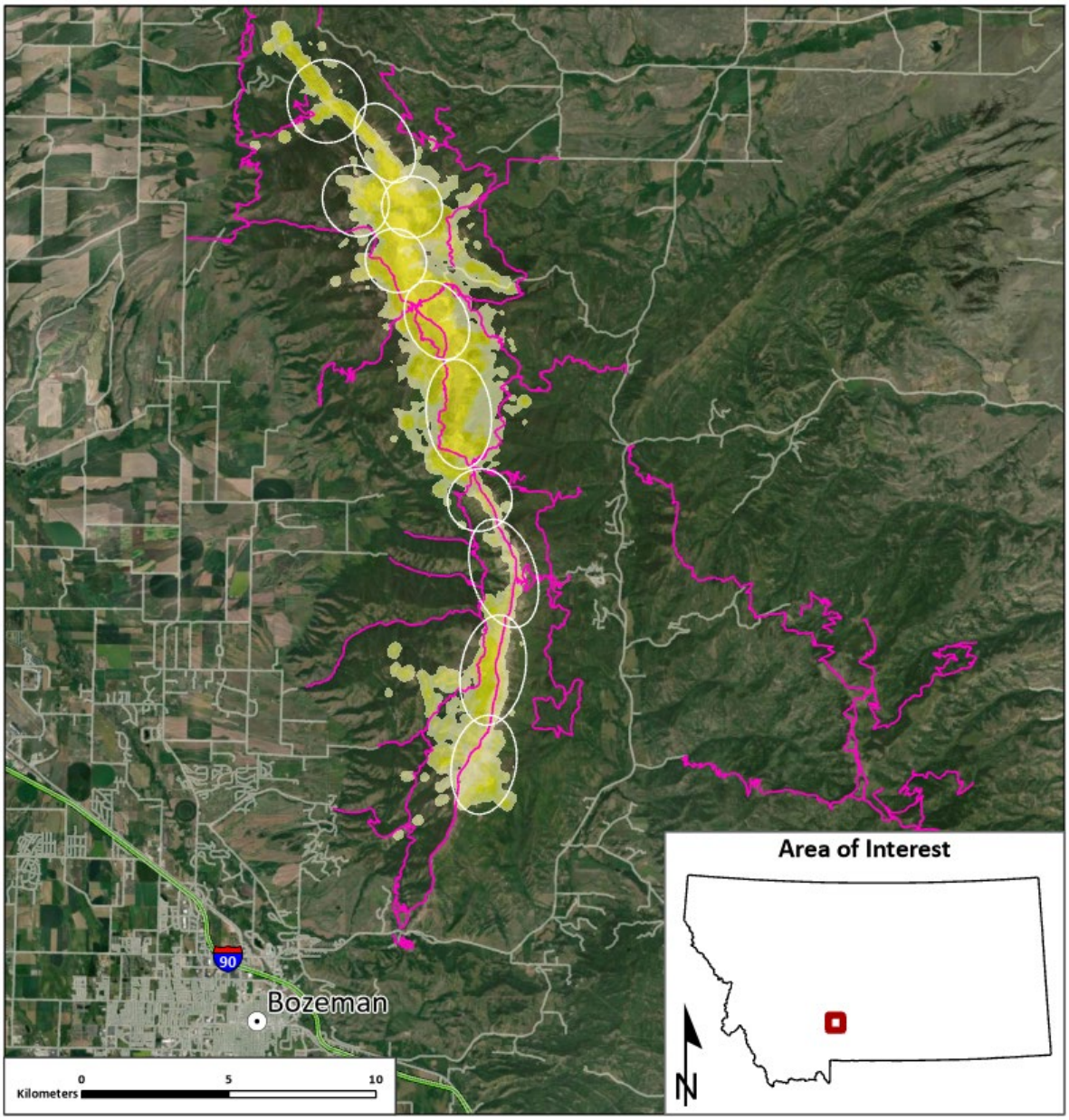

Figure 2. Bridger Mountains, southwest Montana, with mountain goat distribution (yellow) from 14 GPS-collared goats (11 females, 3 males), trails in yellow and observation areas in white.

METHODS

Ground Counting Methods

The RMGA and MFWP organized 3 citizen scientist ground counts: August 8, 2021; July 23, 2022; and July 15, 2023. We required volunteers to attend an evening training session on the Friday immediately preceding the Saturday counting day. Training sessions taught volunteers to classify goats by age and sex using a 9-minute video produced by the RMGA (*https://youtu.be/bgC-iIuZieI*). Volunteers were also trained on how to collect data and assigned observation areas. We directed volunteer groups of at least 2 observers to one of 11 prespecified observation areas designated by known goat concentrations, viewsheds, and safe access (Figure 1 and Figure 2). Observation areas were approximately 4–8km^2. We directed observers to hike to up to observation points within each observation area. Observers counted all goats seen while they were in the field. By design, viewsheds from adjacent observation areas overlapped slightly, thus reducing the likelihood of missing a goat group. We ensured all volunteers had binoculars and spotting scopes to search for mountain goats. The survey window was between 4pm and 9pm on the evening of the survey. We selected this timeframe because it was a period of high mountain goat movement activity, suggesting they would be more visible than during a time when they may be bedded (Figure 3). This study design saturated known mountain goat habitat with observers within a small temporal window during a time of high goat activity and provided a snapshot of goat presence while minimizing likelihood of goat movement between viewing areas. To prevent introducing bias, we did not tell volunteers where the GPS-collared mountain goats were before or during their surveys, nor did we locate the collared goats before the surveys.

Observers recorded location of goats using topographic maps, hand-held GPS units, or phone-based applications such as onX™. We recorded the time of observations, including when they first saw the goats and when they last saw them. We recorded behavior of the goats, particularly if goats were moving and if so, in what direction. We recorded the total count, and if possible, classified the groups to males, females, and young of the year. Finally, we recorded the presence of a radio-collar on any goats in the group. In instances marked goats were observed but the collar was not detected due to distance or thick fur, we determined after the survey whether the timestamp and GPS location aligned with the groups observed and therefore whether that collared animal was likely in that group.

DATA ANALYSIS

We used ArcGIS software to map all locations within the assigned survey window of 4pm to 9pm. Based on average observed step-length (Figure 3), locations within 1,000m of one another could possibly be duplicate observations of the same individual(s). If the same team saw different groups of different composition within 1,000m of one another, these were different groups. If observed by different teams, groups of similar composition (i.e., nanny and kid groups or groups of billies) were considered duplicates. Removing duplicates and summing remaining counts yielded a total minimum count for each survey.

We downloaded GPS data to determine where goats were during the survey window. We overlaid the observers' locations and the mountain goat GPS data and notes of whether collars were observed to determine the number of collared goats that were observed (i.e., recaptured).

We estimated population size using Chapman's modification to the Lincoln-Peterson mark recapture model (Chapman 1951). Chapman's adjustment reduces bias when population sizes are small.

$$N_{est.} = \frac{[(n_2 + 1)(n_1 + 1)]}{m + 1} - 1$$

Where $N_{est.}$ = the estimated population size, n_1 = the number of marked animals present, n_2 = the total number of animals seen (marked and unmarked, i.e., recaptured) and m = the number of marked animals seen. We calculated approximate 95% confidence intervals (C.I.) by multiplying the square root of the variance by 2 (Chao and Huggins 2005).

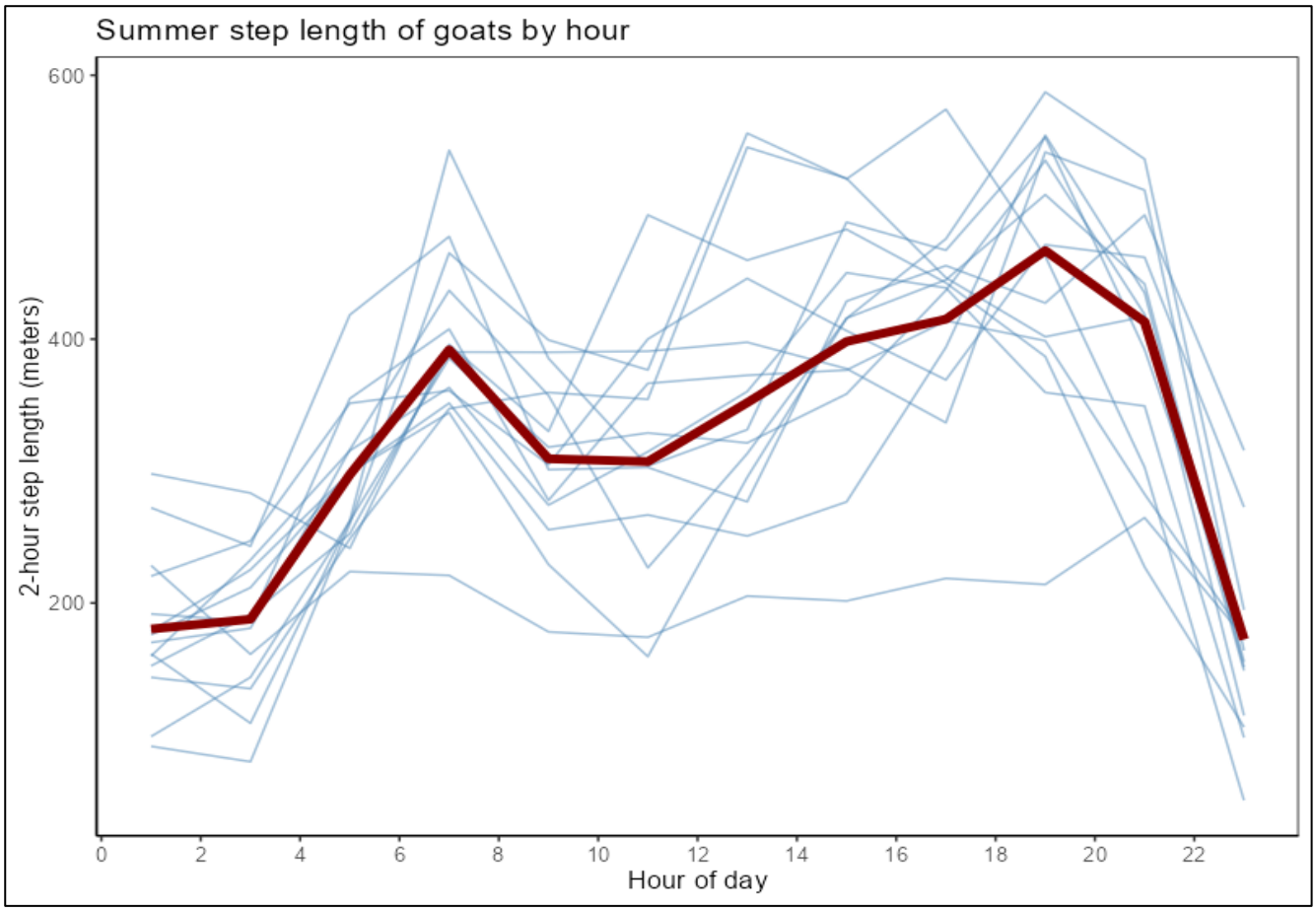

Figure 3. Step length of 14 GPS collared-goats (11 female, 3 male) during 2-hour time intervals during summer months. The surveys were implemented in the 16:00-20:00 time frame when mountain goat movement rates were highest.

RESULTS

We conducted 3 ground-based surveys: 8 August 2021, 23 July 2022, and 15 July 2023, all between 4pm and 9pm. The 2021 survey coincided with hot weather (approximately 30°C) and thick smoke which impeded visibility. The 2022 and 2023 surveys occurred under clear skies with cooler temperatures (approximately 20–25°C). In 2021, teams detected 28 mountain goats in 12 groups and observed 2 of 12 marked mountain goats (Table 1). In 2022, teams detected 93 mountain goats in 32 groups and observed 10 of 13 marked mountain goats. In 2023, teams detected 103 mountain goats in 25 groups and observed 10 of 12 marked mountain goats.

The Peterson-Chapman population estimates for 2021, 2022, and 2023 were 102 (approximate 95% C.I. 19–184), 119 (approximate 95% C.I. 89–149), and 122 (approximate 95% C.I. 96–148). Of 22 instances marked goats were observed, there were 6 instances the collars themselves were not seen, either due to distance or to the thick fur obscuring the collar visibility. Observers correctly identified the sex of the collared goats 15 of the 16 occasions when collars were observed. There was one case when a collar was seen but observers classified the goat as “unknown sex adult”.

Table 1. Year of mountain goat count in Bridger Mountains, with total goats seen (after potential duplicated were removed), the number of kids, yearlings, males, females, unclassified adults, unclassified goats, number of radio collared goats seen versus the number available to be seen, and the Chapman-corrected Peterson population estimate with approximate 95% confidence interval (C.I.).

Year	Total	Kids	Yearlings	Males	Females	Unc. Ad.	Unc. All	Collared goats seen/avail.	Population estimate (+/- 95% C.I.)
2021	28	6	3	8	3	0	8	2/10	102 (19–184)
2022	93	16	8	16	28	11	14	10/13	119 (89–149)
2023	103	22	10	17	33	17	4	10/12	122 (96–148)

DISCUSSION

The 2022 and 2023 ground surveys in the Bridger Mountains resulted in a high proportion of the collared individuals detected (77–83%), sightability which is comparable to some aerial surveys (Rice et al. 2009). The 2021 survey was negatively impacted when thick smoke from western wildfires rolled in unexpectedly and reduced visibility. Furthermore, the temperature was 5–10°C hotter during the 2021 survey than the 2022 and 2023 surveys, potentially prompting mountain goats to seek thermal shelter in less-visible locations like under shady cover or in crevasses.

Ground counts may be an effective population surveillance method in a study area like the Bridger Mountains where trail densities are high facilitating easy access to goat habitat, where expected goat distribution is restricted enough for several teams to observe the area completely, and where goats are less likely to use hiding cover (DeVoe et al. 2015). In larger wilderness areas with more continuous goat habitat, or areas where goat visibility may be obscured by vegetation, researchers may need to consider using more teams of people and developing a study design to sample over space and time as described in Belt and Krausman (2012) and DeVoe et al. (2015). If wildlife managers are uncertain, comparing ground counts with aerial surveys may indicate which method(s) are preferred for that geography (Reynolds et al. 2022).

Montana Fish, Wildlife and Parks has been employing citizen-science ground counts in partnership with RMGA since 2013. These counts began in the Henry's Mountains (approximately 44.771, -111.388), an isolated mountain range approximately 120km south of the Bridger Range. Mountain goats pioneered into the Henry's Mountains and were first documented in 2010. The Henry's Mountains have similar features with the Bridger Range: mountain goat distribution generally occurs above treeline and is a small spatial area (approximately 70km^2) and goat habitat is readily accessible by trail. Five ground-based surveys run in 2013, 2018, 2020, 2022, and 2024 counted 46, 58, 77, 101, and 112 goats respectively (MFWP, unpublished data). During the 2018 survey, MFWP worked together with Idaho Fish and Game (IDFG) to collaboratively survey the area: MFWP and RMGA did a ground survey and IDFG conducted a helicopter flight survey over the same area within 2 weeks of the ground count. The ground survey returned 58 goats with 14 kids, and the IDFG helicopter survey returned 57 goats with 14 kids. The agreement between these 2 survey methods suggested similar sightability rates and that ground surveys could be an effective methodology in this mountain range as well.

Selecting and training observers is key to effective surveys. Montana Fish, Wildlife and Parks and RMGA worked together to select volunteers to assign to each observation area. Rocky Mountain Goat Alliance volunteers were often capable hunters with particular interest in mountain goats, experienced backcountry hikers with good optics and familiarity with searching for wildlife. The training session held before each count was key to ensuring volunteers accurately classified goat groups. Correct field classifications allowed for easy removal of duplicate records because total count, age, and sex classifications were similar.

MANAGEMENT IMPLICATIONS

For some agencies managing mountain goats, simple citizen science ground-based counts may be effective and replicable methods to monitor populations. Sightability rates may differ between study areas, and success of the counts could be influenced by the training and abilities of volunteers, the knowledge of mountain goat distribution and

viewsheds in planning observation points, by weather conditions during the surveys, and by geospatial factors intrinsic to survey areas. Areas with high trail densities, predictable goat distributions, and high visibility (i.e., areas without dense shrub growth and where mountain goats avoid canopy cover) may increase the success of ground-based counts.

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