



Alpine vegetation composition and structure monitoring for Great Sand Dunes National Park and Preserve

2020 Trip Report



CNHP ecologists measuring plant community composition above 13,000 feet in Great Sand Dunes National Park. The unnamed peak, SIX, is one of four surveyed GLORIA summits in Great Sand Dunes National Park. Photo: Sarah Marshall. August 2020.

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Summary and Background

The purpose of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. The Rocky Mountain I&M Network (ROMN) identified vegetation composition, structure, and soils as a vital sign that can be used to better understand the condition of park ecosystems (Britten et al. 2007).

An alpine monitoring site was established in Great Sand Dunes National Park and Preserve (GRSA) by the ROMN in 2008 to study the impacts of climate change on alpine vegetation composition and soils over time. The monitoring protocol follows the Global Observation Research Initiative in Alpine Environments (GLORIA) methods. The timeline for activities at this site includes the following events:

- In 2008, an alpine monitoring site was established at GRSA following GLORIA guidance.
- In 2009, four sentinel sites were established and sampled on four unnamed peaks on the ridge extending north from Mount Herard (referred to as MUD, HUK, PAD, and SIX; Ashton 2010). The peaks range in elevation from 3,550 to 4,000 meters.
- In 2015 and 2020 CNHP crews fully surveyed the four sentinel sites, including all 1-m² quadrat clusters and summit area sections. All soil data loggers were collected and replaced at each peak. Crews collected soil chemistry samples in 2015, but not in 2020, following guidelines in the monitoring protocol to collect soil samples every 10 years. Soil samples should be collected again in 2025.
- The 2015 sampling event occurred over 3 separate trips, totaling 12 days and extended partly due to a crew member experiencing altitude sickness during the first field visit. The 2020 sampling event occurred over a single 7-day field hitch, including travel. 2020 field logistics were complicated by the global COVID-19 pandemic, including restrictions on gathering in groups and sharing vehicles.

GLORIA sites are typically surveyed every five years for vegetation composition, structure and soils. Site establishment and baseline monitoring were carried out in 2009. Due to logistical challenges and concurrent GLORIA re-sampling at Rocky Mountain National Park, the first revisit occurred in 2015. In 2020, sites were fully surveyed again, following guidance from the NPS and GLORIA protocols. The purpose of this report is to outline the basic timeline of sampling, any irregularities or errors in surveying, and logistical details that may benefit future survey crews.

Acknowledgments

We would like to thank all who assisted with field work, training and preparation, and gave knowledge and insight necessary for the GLORIA study, particularly Michael Hoening, who volunteered a full week of field time to help complete the survey in a year with unique time, and logistical challenges associated with the COVID-19 pandemic. Special thanks also go out to the staff of Great Sand Dunes National Park for coordinating our safety check-ins and aiding with our backcountry itinerary.

Introduction

The Rocky Mountain I&M Network (ROMN) adapted an alpine monitoring protocol from the Global Observation Research Initiative in Alpine Environments (GLORIA), an international monitoring network established in 2001, to assess and predict biodiversity and temperature changes in alpine communities in response to drivers like climate change (Pauli et al. 2004). The goals of the GLORIA program are to provide a global baseline for vegetation monitoring in alpine environments and to assess the risks of biodiversity loss and ecosystem instability from climate change. The methodology is extended by cooperators, such as the ROMN and the Colorado Natural Heritage Program (CNHP), to create a long-term monitoring network at the global scale.

In 2020, a field crew from CNHP and one volunteer sampled all four summits (Figure 1) within Great Sand Dunes National Park and Preserve (GRSA) over the course of seven days. The following summary outlines key information about how the site was sampled, and lessons learned that may be applied to future sampling events.

Training

Prior to conducting field surveys at the GRSA site, the field crew (Tom Baldvins, Terutaka Funabashi, Michael Hoening, and Trent Kelly) coordinated remotely with Sarah Marshall (CNHP project lead) in order to familiarize everyone with survey and safety protocols, and the purpose and need of using the GLORIA research methods. In a typical year, the group would have met in person for a half-day training, but this was not possible due to restrictions on gatherings due to the COVID-19 pandemic. Sarah and Terutaka were already familiar with the GLORIA protocol after sampling the Rocky Mountain National Park GLORIA site in 2019.

Given the frequency of lightning storms in the Sangre de Cristo Mountains, the crew reviewed weather and lightning safety procedures along with other general safety protocols. It was agreed that anyone on the crew could “call stop” if they felt unsafe due to impending weather or other conditions, and the crew would gather to briefly discuss safety concerns, assess potential actions, and act as needed to maintain group comfort and safety.

Additional COVID-19 safety protocols were reviewed prior to the field visit due to the ongoing pandemic, including crew members monitoring symptoms daily, traveling in separate vehicles (with the exception of members of the same household), wearing masks and maintaining a minimum of 6 feet of distance between crew members, and sanitizing hands and shared equipment with rubbing alcohol in accordance with current public health guidance at the time.

Camp and Site Access

The crew met in Westcliffe, Colorado to top off vehicle fuel before driving to the first trail to access the GRSA summits on the east side of the Sangre de Cristo Mountain Range. From Westcliffe, the crew headed south on CO-69S to a right turn on County Road 559 and followed

CR559 for 9 miles (Appendix B). The crew continued straight on CR 559.1 and turned right to stay on CR 559.1 at approximately 1.8 miles. From this point, the crew followed the road (marked as Forest Road 412) for another 0.75 miles to a pull-off where a sign indicated that the road was restricted to vehicles less than 50 inches wide. *Note: the access road (Pass Peak Rd.) used in 2015 is now closed to the public, and the entrance off CO-69S is blocked by a fence.*

A backcountry campsite (13S 0458693E 4193744N, WGS84), near the site referred to as “North Basecamp” by the 2015 crew, was utilized for the first part of the sampling week for access to MUD, HUK, and PAD (Appendix B). The crew was able to follow an overgrown road and a faint human/game trail for most of the hike to the campsite, which took the crew approximately 2 hours to reach from the trailhead. Some slope erosion obscured the trail on the way to the campsite and resulted in some overland travel, but the crew was able to follow the trail for the entire way out. The campsite was reasonably flat, with a short hike to a stream north of camp for water. The stream barely had enough water for standard water filtration pumps in 2020, potentially due to the drought. While the Park Service does not require bear cannisters in Great Sand Dunes National Park, the crew brought bags and cord to hang food to prevent wildlife access.

There are no defined trails to the summits of HUK, MUD, and PAD, but the crew found abundant old hunting trails and game trails to follow for easy hiking through forested areas and slopes leading to the summits. A topographic map with the north basecamp (Camp 1) and routes used to access all three summits is included in Appendix B.

In order to access SIX during the second part of the field week, the crew camped at a backcountry site in the vicinity of Medano Lake, located approximately 3 miles up the Medano Lake trail. Reservations are not required for backcountry campsites. The road between the first trailhead and the Medano Lake trailhead (CR 559.1) was passable for regular SUVs and one Subaru Outback east of Medano Pass. The crew parked one rental SUV with slightly lower clearance at the pull-off at the pass. From the pass to the Medano Lake trailhead, the Subaru Outback barely had enough clearance to get to the trailhead given large ruts and rocks in the road. When the crew arrived at the trailhead, there wasn’t enough room for all crew vehicles and the crew packed and organized gear while waiting for additional parking spots to become available. The crew was able to double-park vehicles in a long parking space to save space for other trailhead users. If the road continues to deteriorate between Medano Pass and the Medano Lake trailhead, it may be advisable for future crews to hire a local 4WD outfitter to shuttle people from Medano Pass to the trailhead. Also, the road conditions would likely deteriorate following a substantial summer rainstorm, and future crews should consider this possibility in their trip planning. Additionally, one of the crew members lost his keys during the second portion of the field survey, and given the rental car company’s lack of spare keys, had to have his vehicle towed out of the trailhead parking area in the weeks following the field survey by a towing company based in Westcliffe.

At the Medano Lake campsite, the crew was able to filter water from a stream immediately adjacent to the campsite. It is worth noting that future crews may want to scout the trail to the summit ridge for SIX during daylight hours. The 2020 crew used a well-traveled climbing trail, which differed slightly from the GPS tracks from the 2015 GLORIA crew, particularly around the willow carr surrounding the lake (climber's trail diverges and heads slightly uphill of the trail used by the 2015 crew).

Research Site

GLORIA sites are established on the tops of peaks (summits) and the summits vary from just above tree line to the highest life zones of vegetation. Within one region, all four summits share qualitatively similar geology, climate, disturbance, and land-use history leaving vegetation differences among the summits to be driven primarily by elevation. The four summits chosen within Great Sand Dunes are in close proximity to one another (all within about 4km) on a ridgeline extending north from Mount Herard (Figure 1).

Table 1. Name, elevation, and vegetation zone of the four alpine sites within the target region of Great Sand Dunes National Park and Preserve

GLORIA Summit code	Summit name	Elevation (m)	Vegetation Zone
SIX	Unnamed	4,000	Alpine/nival ecotone
PAD	Unnamed	3,870	Upper alpine
MUD	Unnamed	3,700	Lower alpine
HUK	Unnamed	3,550	Lower alpine/subalpine ecotone

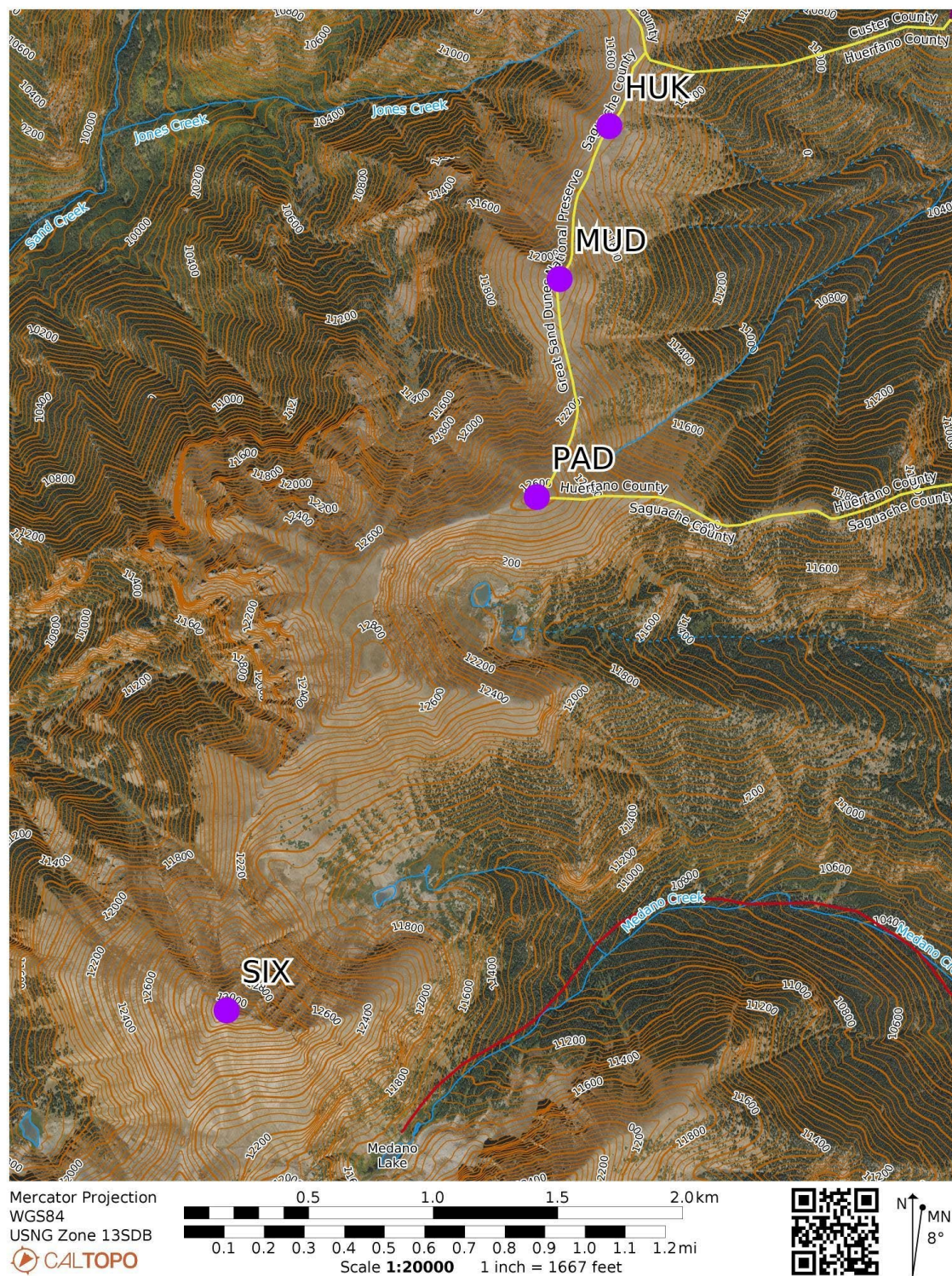


Figure 1. Locations of the four GLORIA peaks in Great Sand Dunes National Park and Preserve. The yellow lines mark the boundary between Saguache and Huerfano Counties. The red line represents the established trail to Medano Lake.

Field Sampling

The 2020 alpine growing season was likely impacted by the entire park being under extreme drought conditions (Figure 2) during the field sampling visit, compared to above-average mountain snowpack and no drought for the same period in 2019 (National Drought Mitigation Center, 2021). The effects of drought were most noticeable on the west-facing aspect of SIX, where many of the graminoids were prematurely dry and brown. In general, the drought did not appear to hinder detection of key species, but occasionally made identification more challenging and may have skewed detected species and cover values. For species with limited flowering parts, field botanists used a preponderance of evidence (form, nearby mature plants, ligule characteristics, etc.) and familiarity with certain species at different life stages where applicable to make the identification. Species with lower confidence at the genus or species level were flagged on each data form using appropriate codes.

During data entry and QC, there were several instances across summits where visual estimates for top cover exceeded the cover sum for the 1m² quadrats (Form 2). In order to address this error, we reviewed quadrat photos in the office to check and occasionally re-assess cover values for top cover of surface types, and for some dominant species that were clearly visible in the photos (e.g., *Carex rupestris*). For forms where this post-field review was needed, we made notes in the comments section of each form.

The CNHP crew sampled all 4 summits comprising the GRSA GLORIA site over the course of six days. A summary of site access and set-up is provided by summit, along with notes on observations and potential sampling errors. The general timeline of sampling activities is provided below, which allowed flexibility as we had more or fewer crew members available throughout the sampling effort.

1. Locate high summit point; cache gear.
2. Establish cardinal directions; find corners of quadrat clusters and flag “no-walk” areas in these locations.
3. One team would begin taking overview photos, and replacing/photographing temperature loggers, and move on to completing the land use and disturbance forms. A second team (sometimes just one person) would immediately begin summit area section species lists. A third team would begin with the vegetation quadrats, and would be joined by the first team when their tasks were complete.

Descriptions of how each peak was sampled including number of sampling days and crew members, site access, notes on field measurements, general observations, and potential sampling errors are provided below in the order that peaks were sampled in 2020. HUK was sampled first, as it is the easiest peak to access from the north basecamp. MUD, the second easiest peak to access, was sampled next, followed by PAD. SIX was accessed via the

Medano Lake backcountry campsite. SIX was sampled last, after the crew was well-acclimated to working at altitude and well-practiced with the GLORIA protocol.

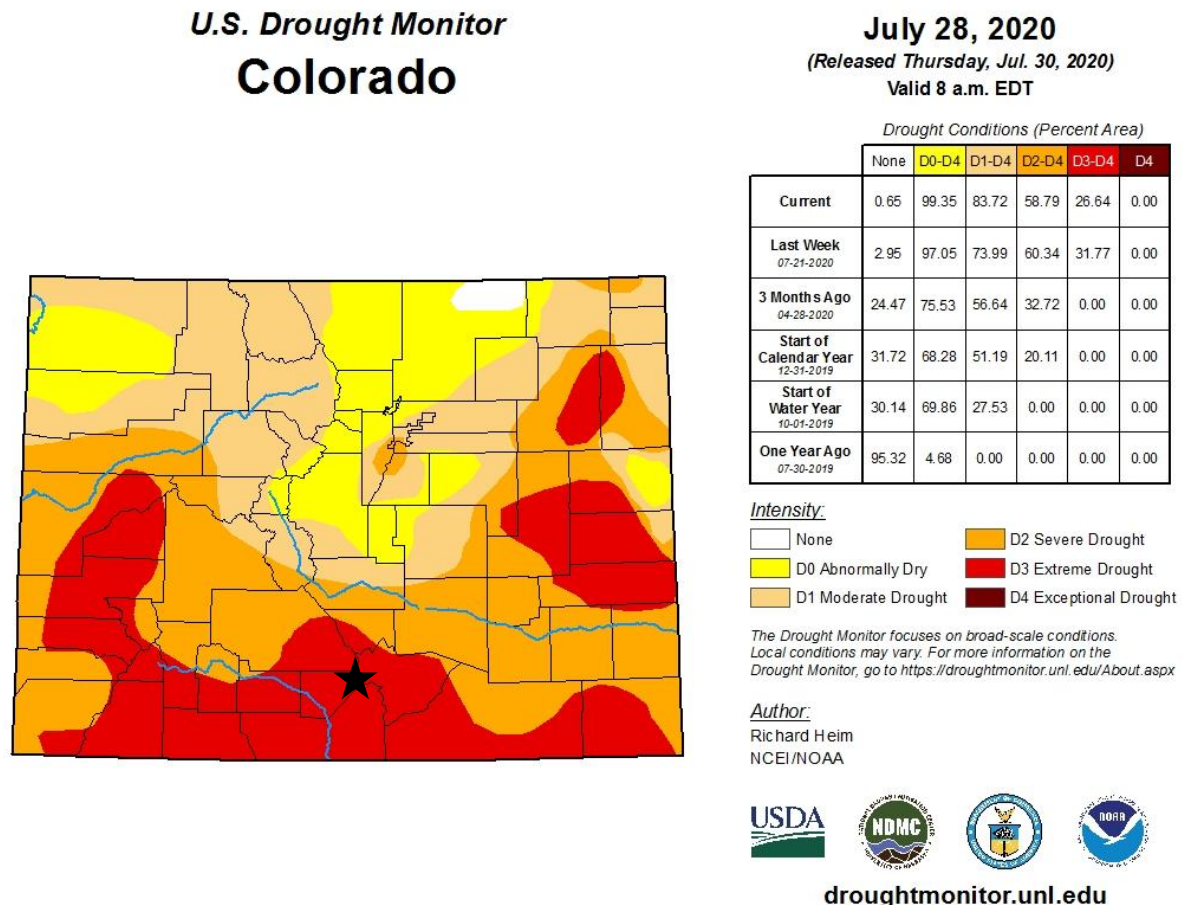


Figure 2. U.S. Drought Monitor Map for Colorado at the time of GLORIA Great Sand Dunes sampling in 2020. Star shows the location of the GLORIA site

HUK

The crew took a total of 1.5 days to sample HUK. The first day included calibration to ensure that new crew members were familiar with the GLORIA protocol, and common plant species in the area. The time needed to sample plots gradually decreased as all crew members became more familiar with plants and the sampling protocol.

Site Access and Set-up

HUK is located less than 1 km overland from the northern basecamp (“Camp 1”). It took around an hour to hike up to the summit of HUK carrying field gear. The crew headed down the hill just after 3:00pm on the first sampling date due to the threat of an incoming storm. Tree line is

approximately 0.5 km from HUK heading straight down the mountain toward camp (not required in 2020).

The crew used HUK as a calibration peak, including site set-up, to ensure consistency in plant ID and plot sampling across researchers (Figure 3). The crew did not encounter any difficulties (missing plot markers, etc.) in setting up HUK.

Observations and Sampling Errors

The crew was able to easily locate all monuments and temperature loggers. The east quadrat logger was completely exposed to the air and sitting on a rock.

The crew occasionally had difficulty distinguishing between lichen on rock vs. lichen on bare ground and surface types in top cover estimates on the north aspect of the summit, given abundant lichen. Most lichen appeared to be epilithic. The crew also noted abundant rodent burrows and mounds in the 10 m SAS of the western aspect of the summit. Other crew notes included potentially missing some *Minuartia rubella*, as some of the *Minuartia* spp. on the peak were lacking flowers. Overall, *M. rubella* appeared to be less common than *Minuartia obtusiloba*.

Some initial errors in cover estimates on the HUK peak were potentially due to the experiential learning curve of several crew members who had no previous experience with the GLORIA protocol. Throughout the sampling period, the crew adopted a standard procedure where a more experienced botanist or plant ecologist was paired with a less experienced data recorder. Unknown plants were flagged in plots and marked on data forms as needed, in order to not interrupt the flow of data collection. A more experienced crew member would periodically check in with all teams and visit the flagged plants and either identify in the field or collect to key out back at camp.



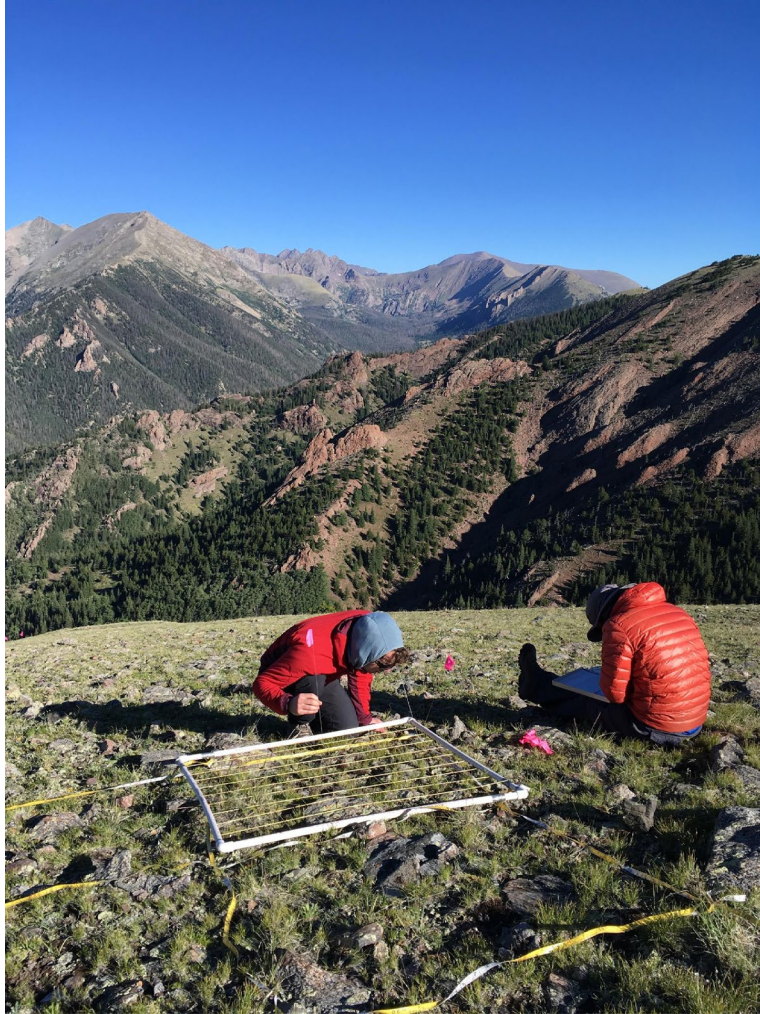
Sampling quadrats on HUK in Great Sand Dunes National Park (July, 2020; photographed by Sarah Marshall).

MUD

The crew took one full field day to sample MUD, beginning at 11am after finishing HUK and working until 6pm after taking advantage of a full day of good weather and close proximity to camp.

Site Access and Set-up

The crew accessed MUD from HUK, traveling overland along the ridge between the peaks to reach the site. The crew returned to basecamp from MUD. Access was relatively easy, and the crew successfully located all monuments during site set-up. A crew member responsible for locating the plot monuments noted that the direction for intersection lines was not correct on the 2015 data sheet (Form 1). The crew member corrected the compass directions on Form 1 to match the actual monument locations.



Sampling quadrats on MUD in Great Sand Dunes National Park, with a view of Crestone Peak to the northeast (July, 2020; photographed by Sarah Marshall).

Observations and Sampling Errors

Overall plant community composition was similar between MUD and HUK (Figure 4). The crew observed prevalent rodent burrows and soil disturbance caused by rodents on the northern and southern aspects of the peak, and overall high evidence of rodent activity across the peak. Some scattered soil disturbance, mostly due to rodents, was observed on the east-facing aspect. Other crew notes included potentially missing some *Minuartia rubella*, as some of the *Minuartia* spp. on the peak were lacking flowers. Overall, *M. rubella* appeared to be less common than *Minuartia obtusiloba*.

All temperature loggers were relatively easy to find and replace once plots were located.

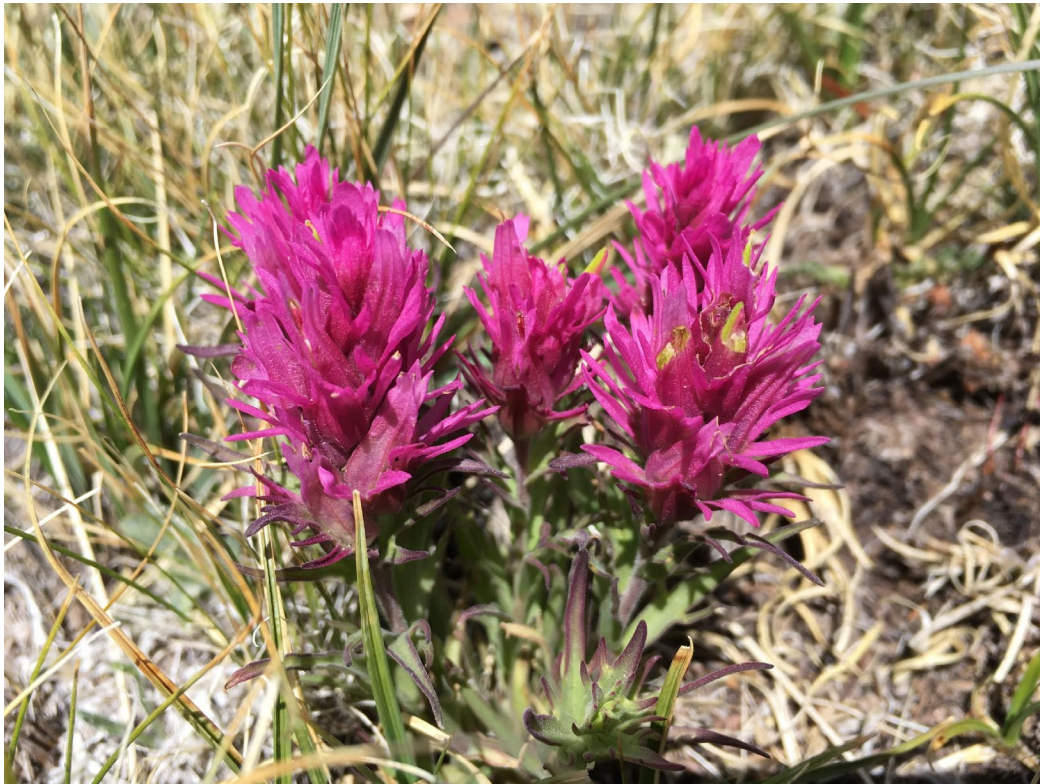
PAD

The PAD Peak took 1.5 days to sample, with the crew leaving the peak at 2:45pm on the first day due to an approaching storm. A team of 2 people hiked to PAD on the second morning to survey three remaining quadrats while the rest of the crew packed up camp to all hike out to the trailhead.

Site Access and Set-up

The crew accessed PAD via overland travel and occasional game trails through scattered patches of krummholz vegetation, followed by attaining and traveling along the ridgeline between MUD and PAD (Appendix B). Total travel time was 1.5-2 hours on the way to the summit and 1-1.5 hours on the way back to camp. The crew was able to more rapidly get to treeline due to the sudden storm on the first day by heading northeast off the summit to get off the ridge and then traversing along game trails toward dense krummholz and eventually taller forest cover.

During site set-up, the crew noted that the compass direction was slightly off for the east quadrat (on Form 1 from 2015). The corrected compass directions were recorded on Form 1.



Castilleja haydenii on the PAD summit in Great Sand Dunes National Park (August, 2019; photographed by Sarah Marshall).

Observations and Sampling Errors

The crew observed abundant soil slumping, creating small terraces, on the north aspect. Soil slumping may have been partly caused by elk travel across the slope, which was evident lower on the hillside outside the summit area sections. As with previous peaks, the crew may have potentially missed some *Minuartia rubella*, as some of the *Minuartia* spp. on the peak were lacking flowers. Overall, *M. rubella* appeared to be less common than *Minuartia obtusiloba*.

All temperature loggers were relatively easy to locate and replace.

SIX

SIX was the most difficult peak to survey due to its longer and steeper access, topographic complexity and steepness, high elevation (above 13,000'), exposure to thunderstorms with an approximately 2.5 km distance from summit to tree line, and unpredictable weather patterns. The full CNHP crew (5 members) sampled most of the site in one day before being chased off the summit by an early, sudden thunder and hail storm, and a smaller team of two returned the following day to complete several remaining plots.

Site Access and Set-up

SIX can be reached by following a climber's trail between Medano Lake and Mount Herard, and branching off to the north at the saddle on the ridge between Mount Herard and SIX and following the ridgeline all the way to the summit. On the first sampling date, the crew followed waypoints from the 2015 crew, but had to briefly wait until daylight to find that the original trail had been relocated further up the hill, and away from the lake. The trail first traverses the hillside above the lake, then follows a grassy topographic ramp that cuts up to looker's right of the rock wall and waterfall at the head of the valley above Medano Lake. From there, the trail continues, but becomes faint and is marked by cairns all the way to the saddle between Mt. Herard and SIX. The ridgeline is Class I-II scrambling across scree and boulders, but was comfortable for the crew and is a lower-impact way to travel to the summit. The hike from the campsite took approximately 1.5 hours up, and 1 hour back to the trailhead. The crew used an alternate, more direct downhill route following a grassy debris fan from the peak when the storm was approaching on the first sampling day, similar to the route used by the 2015 crew. This route is not recommended for normal (non-storm) use because it traverses less durable surfaces (alpine vegetation, scree, etc.) and steeper terrain.

During site setup, the crew noted that the pSW-5 intersection line distance recorded on Form 1 from 2015 was longer than seemed typical (likely a 5 m drop in elevation rather than a straight line across). The 2020 crew kept the same distance as the 2015 crew for consistency, and recorded corrected intersection line values on Form 1. No data were recorded for the 10 m intersection lines due to loose rock and steep drop-offs, though the crew did their best to follow lines of sight for all associated observations.

Observations and Sampling Errors

By the time the crew sampled SIX, they had multiple field days of experience with the GLORIA protocol and plant species in the area. Crew members had also settled into a rhythm of task division and maximizing each member's respective strengths and skill sets. Plant species were very similar to HUK, MUD, and PAD, which helped to greatly reduce the time required for sampling.

Portions of the eastern summit area section were difficult to safely sample due to loose scree and generally rocky, steep, and exposed areas (especially in some of the rock crevices in the southern portion of the section). As with previous peaks, the crew may have potentially missed some *Minuartia rubella*, as some of the *Minuartia* spp. on the peak were lacking flowers. Overall, *M. rubella* appeared to be less common than *Minuartia obtusiloba*.

All temperature loggers were relatively easy to find and replace. The east temperature logger was in the lower left corner of the E 3,2 quadrat, vs. the typical center quadrat (E 2,2). The logger was replaced in the same location, to maintain consistency with previous site visits.

Notes for Future Sampling

General Tasks Prior to 2025 GLORIA Sampling Event

1. Rebuild and/or replace 1m x 1m quadrat frames. Most of the old wooden frames are warped and/or broken, and the PVC frames should be adapted to allow for line-point intercept "hits" at the intersection of the string grid.
2. Consider making a new photo pole that is compatible with the GLORIA manual. We improvised with an adjustable backcountry ski pole.
3. Purchase a new small whiteboard for photos.
4. Create a master plot layout sheet for each site in advance of the field visit. This sheet will include key plot location information (which is often hard to read on old scanned field forms). This would avoid having unnecessary additional forms in the field, and not risk biasing plant lists and ID.

Logistical Notes for Future Sampling Events

1. The typical half day training on CSU campus would be necessary if several crew members were not already familiar with the GLORIA protocol, though the field crew spent additional time at the first field site becoming familiar with the flora. With an inexperienced crew, training could include some time on campus to familiarize the crew with equipment and data collection and a practice plot in the alpine off Trail Ridge Road in Rocky Mountain National Park in an easily accessible location to begin learning the plants likely to be encountered in GLORIA plots. While the plant community at GRSA is different, many of the more common alpine species occur in alpine areas of both parks.

2. At present, it is not possible to reserve campsites at Medano Lake. It is advisable that future crews access the lake on a week day, and anticipate a full parking lot at the trailhead (and potentially full campsites at the lake in a normal year), and plan accordingly.
3. The peak sampling sequence used in 2020 worked well in sampling the closest, lowest-elevation, easiest-access peak first to get the crew calibrated, followed by peaks with increasing elevation gain and/or hiking time.
4. The crew would have benefitted from having an additional crew member, potentially with an additional botanist capable of leading quadrats and/or summit area sections. With an odd-numbered crew, we were typically able to have someone direct crew assignments, “float” and help out as needed with the various crews, and inventory summit area sections when they had a sufficient block of free time.
5. Ensure that the crew is clear on visual estimation of top cover vs. total cover, and calibrated in estimation up front. While the crew covered this at the beginning of the sampling event, there were still several instances where crews recorded top cover values less than total cover, potentially due to working at altitude for extended periods of time.
6. Stress the importance of clear, legible writing on field forms and/or consider digital data collection where possible or more efficient. The 2020 crew did not attempt digital data collection, partly due to being in the backcountry for the entire field sampling period. It may be worth testing digital data collection options prior to the next sampling event in 2025.
7. As time passes from site set-up, the GLORIA database plant names are increasingly different from the latest nomenclature in the *Flora of Colorado* (Ackerfield 2015) used by earlier crews. An update to the latest flora is in progress at present, and a new edition of the flora will likely be available before the next sampling event. The 2020 crew also utilized the keys in *Sedges of Colorado* (Wingate 2017) for *Carex* species.
8. Check the status of the access trails prior to visiting these sites, as the number of unstable standing dead trees and downed trees is likely to increase in the future. Given the status of forests on the approach to all of the GLORIA summits, it would be worth discussing contingency plans in the event of a wildfire as part of the larger backcountry safety plan for the crew – especially for less-traveled areas leading to HUK, MUD, and PAD.
9. The crew had cell phone reception for almost the entire duration of the field sampling period, including both campsites (with better reception at the first campsite), which allowed for crew members to occasionally check the latest NOAA weather forecast (including forecasted and approaching electrical storms) and check in with emergency contacts. The crew also had 2 two-way Spot-X satellite messenger devices for morning and evening check-ins with emergency contacts. In the limited cases where the crew split up, each smaller group would carry a Spot-X unit.

Conclusion

The 2020 GRSA survey crew was able to successfully sample all 4 GLORIA summits at a rate of 1-1.5 days per summit, spread across a total of 7 days including both travel and field work. Efficiencies were gained by dividing the crew into 2 smaller teams on several occasions, allowing the first team to complete a small list of remaining plots on a summit started by the entire crew on the previous day while the other team started setting up the next summit or completed other tasks such as packing up camp.

The 2020 alpine growing season was likely influenced by extreme drought conditions. In general, this did not appear to hinder detection of key species, but occasionally made identification more challenging and may have affected observed vegetation cover and slightly skewed detected plants toward later-blooming species like members of the *Asteraceae* family.

When analyzing the data for 2020, it will be important to note that there were several instances where visual estimates for top cover exceeded the cover sum for the 1m² quadrats (Form 2). In order to address this error, we reviewed quadrat photos in the office to check and occasionally re-assess cover values for top cover of surface types, and for some dominant species that were clearly visible in the photos (e.g., *Carex rupestris*). For forms where this post-field review was needed, we made notes in the comments section of each form.

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Appendix A: US-GRSA 2020 Field Log

Date	Peak	Persons	Activities	Notes
7/28/2020		Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	Travel to trailhead from Fort Collins and Boulder; hike to first backcountry campsite and set up camp	5 hr drive from Fort Collins
7/29/2020	HUK	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	Site set-up, (8) 1m ² cover plots, (4) SAS, all Tidbit loggers replaced and most photos completed; QC and plant ID at camp	Left camp at 7:00 (crew member needed light to pump water); arrived at HUK at 8:45 (original map showed incorrect location of HUK summit, further to the north). Departed HUK around 13:00 due to incoming storm
7/30/2020	HUK & MUD	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	HUK: (8) 1m ² cover plots, (4) SASs, remaining photos; MUD: site set-up, (16) 1m ² cover plots, (8) SAS, all Tidbit loggers replaced and all photos completed; QC and plant ID at camp	Left camp at 5:30; arrived at HUK at 6:15. Departed HUK for MUD at 10:30; arrived at MUD at 11:00. Left MUD at 18:00; arrived at camp at 19:00.
7/31/2019	PAD	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	Site set-up, (13) 1m ² cover plots, (8) SASs; all Tidbit loggers replaced and most photos completed; QC and plant ID at camp	Departed camp at 6:00, arrived at PAD at 7:18. Left PAD for camp at 14:45 due to incoming afternoon thunderstorm; arrived at camp at 15:45.
8/1/2020	PAD	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	Completed (3) 1m ² cover plots (PAD); packed up camp and hiked out to trailhead; drove to Medano Lake trailhead, organized gear, and backpacked in to Medano Lake campsite	Team of 2 departed camp for PAD at 5:45, and arrived at PAD at 6:40. Returned to camp around 9:15. Entire crew hiked from camp to the cars at 10:00; arrived at the cars at 11:15am. Crew arrived at the Medano Lake camp around 16:30.
8/2/2020	SIX	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	Site set-up, (15) 1m ² cover plots, (8) SASs; all Tidbit loggers replaced and most photos completed; QC and plant ID at camp	Departed camp at 5:15, arrived at SIX at 6:45, abruptly left SIX and hiked back to camp around 12:00 due to a sudden hailstorm and incoming thunderstorm (2-3 hrs before forecasted storm).
8/3/2020	SIX	Sarah Marshall, Tom Baldvins, Michael Hoening, Teru Funabashi, Trent Kelly	(1) 1m ² cover plot, and remaining photos completed; packed up camp, hiked out, and drove back to Fort Collins and Boulder	Team of 2 departed camp at 5:00, arrived at SIX around 6:00. Team of 2 returned to camp at 8:00; crew hiked out to trailhead at 9:00 and drove home.

Appendix B: US-GRSA 2020 Route Maps

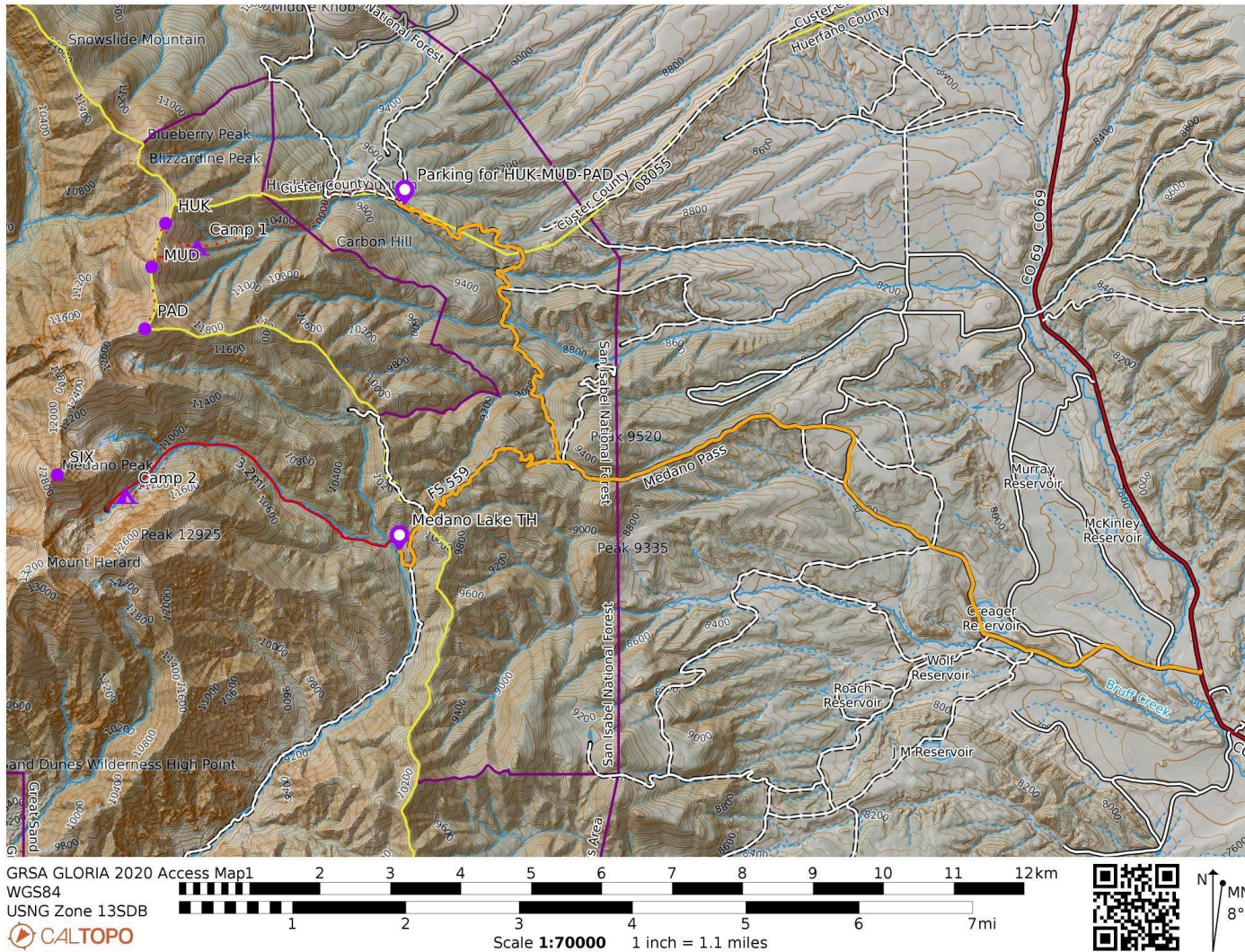


Figure B1: Overview of 2020 access routes to reach trailheads in Great Sand Dunes National Park and Preserve showing the driving route (orange), hiking routes (purple), and campsites (purple triangles).

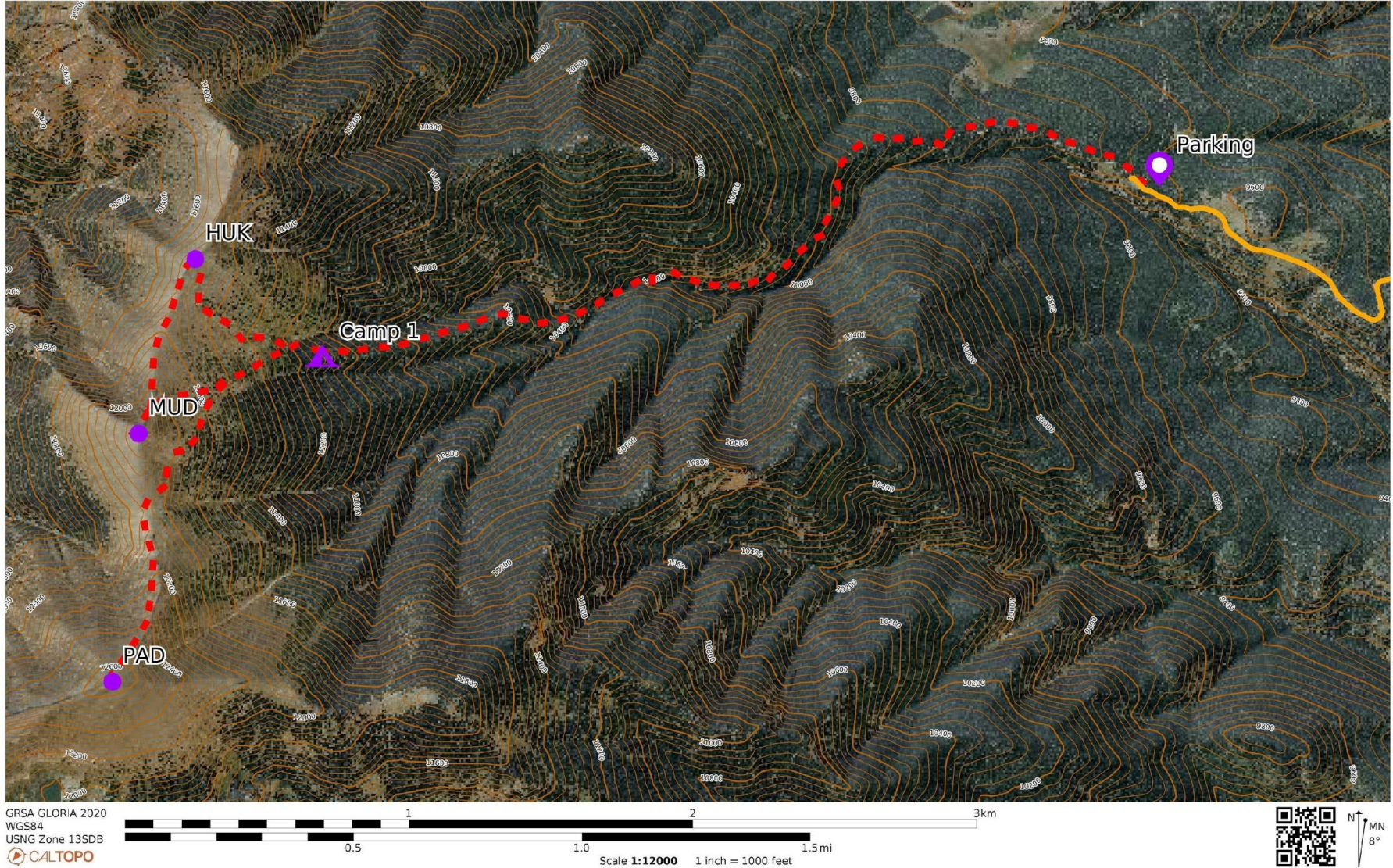


Figure B2: Hiking routes (red dashed line) from the parking area to camp, HUK, MUD, and PAD in Great Sand Dunes National Park and Preserve. Driving route shown in orange.

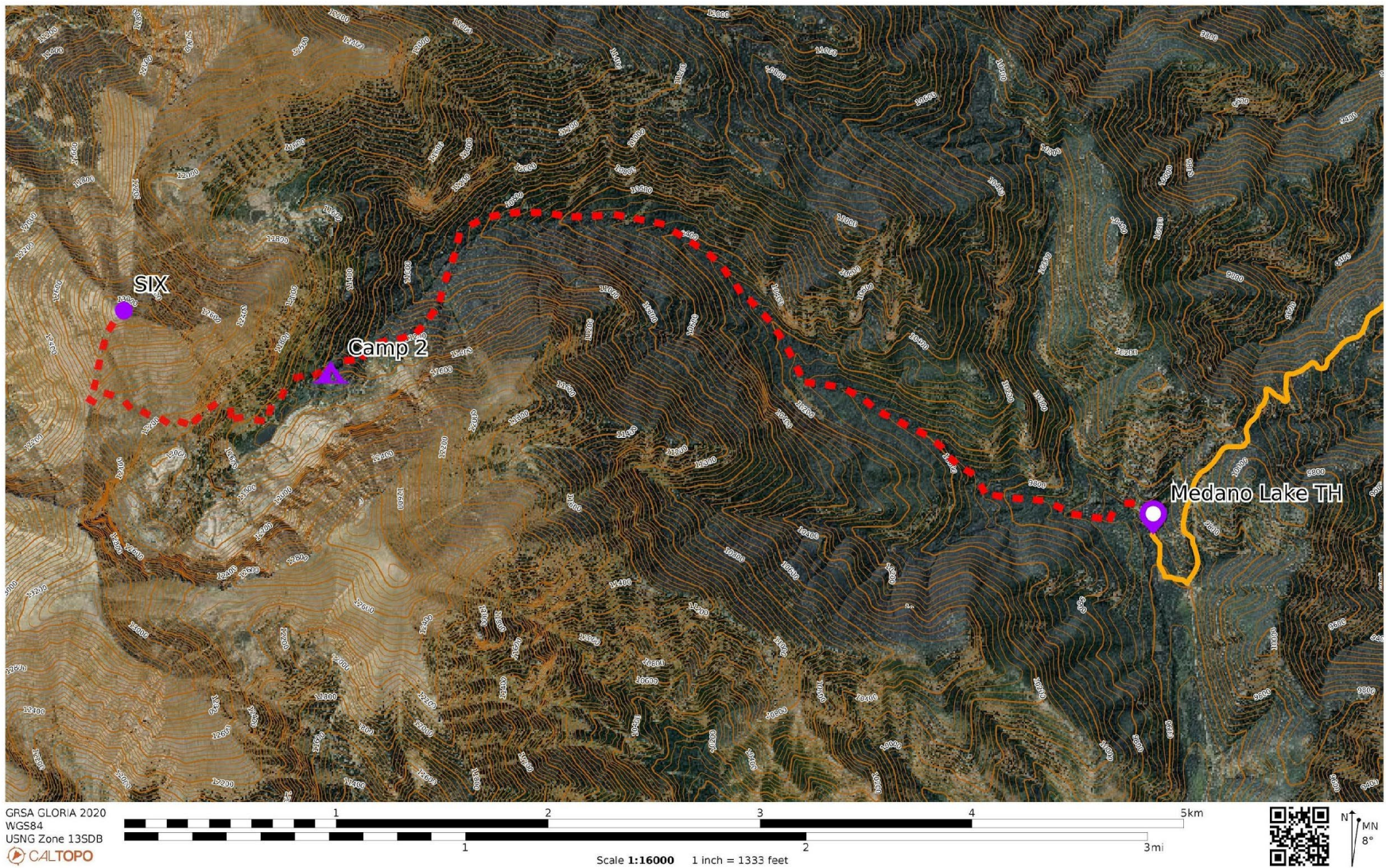


Figure B3: Hiking route (red dashed line) from Medano Lake trailhead to camp and SIX in Great Sand Dunes National Park and Preserve. Driving route shown in orange.



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