



Alpine vegetation composition and structure monitoring for Rocky Mountain National Park

2024 Trip Report



The view from the hike up to Vision Quest. July 2024. NPS/Bodie Spinner

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Executive Summary

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).

The Rocky Mountain National Park (ROMO) Global Observation Research Initiative in Alpine Environments (GLORIA) alpine monitoring site was established by the ROMN in 2008 to study the impacts of climate change on alpine vegetation composition and soils over time. The timeline for activities at this site includes the following events:

- In 2008, an alpine monitoring site was established at ROMO following GLORIA guidance.
- In 2008 and 2009, four sentinel sites were established on Jackstraw Mountain (JSM) and three unnamed peaks on the ridge of Mount Ida, referred to as Pika (PIK), Vision Quest (VQS) and Glacier (GLA). The peaks range in elevation from 3,520 to 3,862 meters.
- The four sentinel sites were partially sampled in 2009 including eight of sixteen established 1-m² quadrat clusters per peak, temperature data logger placement in the center of each cluster at a depth of 10 cm, all summit area sections at each peak, comprehensive photographs at each peak, soil sample collection at each quadrat cluster for soil chemistry and texture, and disturbance at each peak using applicable metrics from the 2008 Disturbance Index and the California Rapid Assessment Method for Wetlands. The optional 10 x 10 m frequency plots and 10 x 10 m line intercept plots were not completed in 2009 due to lack of time.
- In 2010 the four sentinel sites were again partially surveyed. Summit area sections were sampled at VQS and PIK, and five of eight sections were completed on JSM. All sixteen 1-m² quadrat clusters were sampled on JSM, VQS and PIK but not on GLA due to poor weather conditions. The optional 10 x 10 m frequency plots were not completed in 2010 due to lack of time. The 10 x 10 m line intercept plots were completed on VQS and PIK but not JSM and GLA. All soil data loggers were collected and replaced at each peak.
- In 2014 and 2019 the four sentinel sites were fully surveyed, including all 1-m² quadrat clusters and the 10 x 10 m frequency plots. All soil data loggers were collected and replaced at each peak. Soil chemistry samples were collected in 2014 and not in 2019, following guidelines in the monitoring protocol to collect soil samples every 10 years.
- In 2023, all soil data loggers were collected (except VSQ N22 which couldn't be located) and replaced at each peak.

- In 2024, all four sentinel sites were fully surveyed, including all 1-m² quadrat clusters, summit area sections (SASs), disturbance, plot photos, and the 10 x 10 m frequency plots. Soil chemistry samples were also collected.

GLORIA sites are typically surveyed every five years for vegetation composition, structure, and soils. However, sites were visited in both 2009 and 2010 to complete unfinished site setup and surveying. In 2014, 2019, and 2024 sites were fully surveyed following guidance from the NPS and GLORIA protocols. The purpose of this report is to outline the basic timeline of sampling and any irregularities or errors in surveying for the 2024 sampling event, as well as logistical details that may be beneficial for future survey crews. This report includes and builds upon currently relevant information from past trip reports.

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 Kati Zybko, Dana Witwicki, Erin Borgman, and Sarah Marshall. Special thanks also go out to the staff of Rocky Mountain National Park for coordinating our backcountry itinerary, and to CNHP staff for organizing safety check-ins.

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 2024, all four sentinel sites were sampled following the GLORIA protocol, with the adapted ROMN protocol, and anthropogenic factors using the Disturbance Index.

In 2024, a field crew from CNHP and NPS sampled all four summits within the Rocky Mountain National Park (ROMO) GLORIA site over the course of three weeks. 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 ROMO peaks, the field crew (Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, and Bodie Spinner) met at the Ute Trailhead along Trail Ridge Road with Sarah Marshall (CNHP) and ROMN/NPS staff in order to familiarize everyone with survey and safety protocols, species ID, and the purpose and need of using the GLORIA research methods. The group practiced with setting up a 3 x 3 m tape grid and a 1 x 1 m microgrid and dropping pins, as well as calibrating on cover estimates. During these training days, questions about what to call litter arose. In 2024 field sampling, the crew considered scat, vagrant lichen, and dead parts of plants that were still attached to living plants at a 45 degrees or less as functional litter.

Given the frequency of lightning storms during past sampling events, and several rapid retreats from peaks, 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.

Lodging and Access

The Timber Creek campground, located on the west side of Rocky Mountain National Park, was utilized for the first and third weeks of surveying to access VQS, PIK and part of JSM. The Timber Creek campground is approximately two hours from the CNHP office in Fort Collins, CO, 30 minutes from Grand Lake, CO, and 20 minutes to Milner Pass, where VQS and PIK can be accessed. The campground is equipped with several bear-safe boxes for storing food, water spigots for drinking, a dishwashing station, a large bear-safe trash and recycling bin, and several bathrooms with electricity and running water.

In order to access GLA and part of JSM during the second week of surveying, the crew camped at the Jackstraw Lower Campsite, a backcountry campsite located approximately 4.5 miles up the Timber Lake trail. The crew was able to filter water from a stream adjacent to camp. This year, the crew borrowed three bear vaults from ROMN and used three bear vaults from CNHP. Two members of the crew brought their own bear vaults. It is worth noting that crews in the past have encountered several moose in the area, and the 2024 crew encountered a cow and her calf in the wet meadow immediately adjacent to the campsite.

In 2014, a quarter mile section of the Timber Lake trail was closed due to a recent mudslide. As of 2024, the route through the slide area was mostly cleared and passable, but still covered in fallen timber and required climbing over and under several logs with full packs and gear (Figure 1).



Figure 1. Erin Eastman and Bodie Spinner navigate the old, downed trees on the Timber Lake Trail.
NPS/Lauren Laughlin

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 Rocky Mountain National Park are in relatively close proximity to one another (all within ~3 km) on a ridgeline that climbs to Mount Ida, with the lowest site is nearby on Jackstraw Mountain (Figure 2, Table 1). The four peaks have similar geology (mica gneiss, schist and migmatite), similar land use history and disturbance levels, and a similar climate.

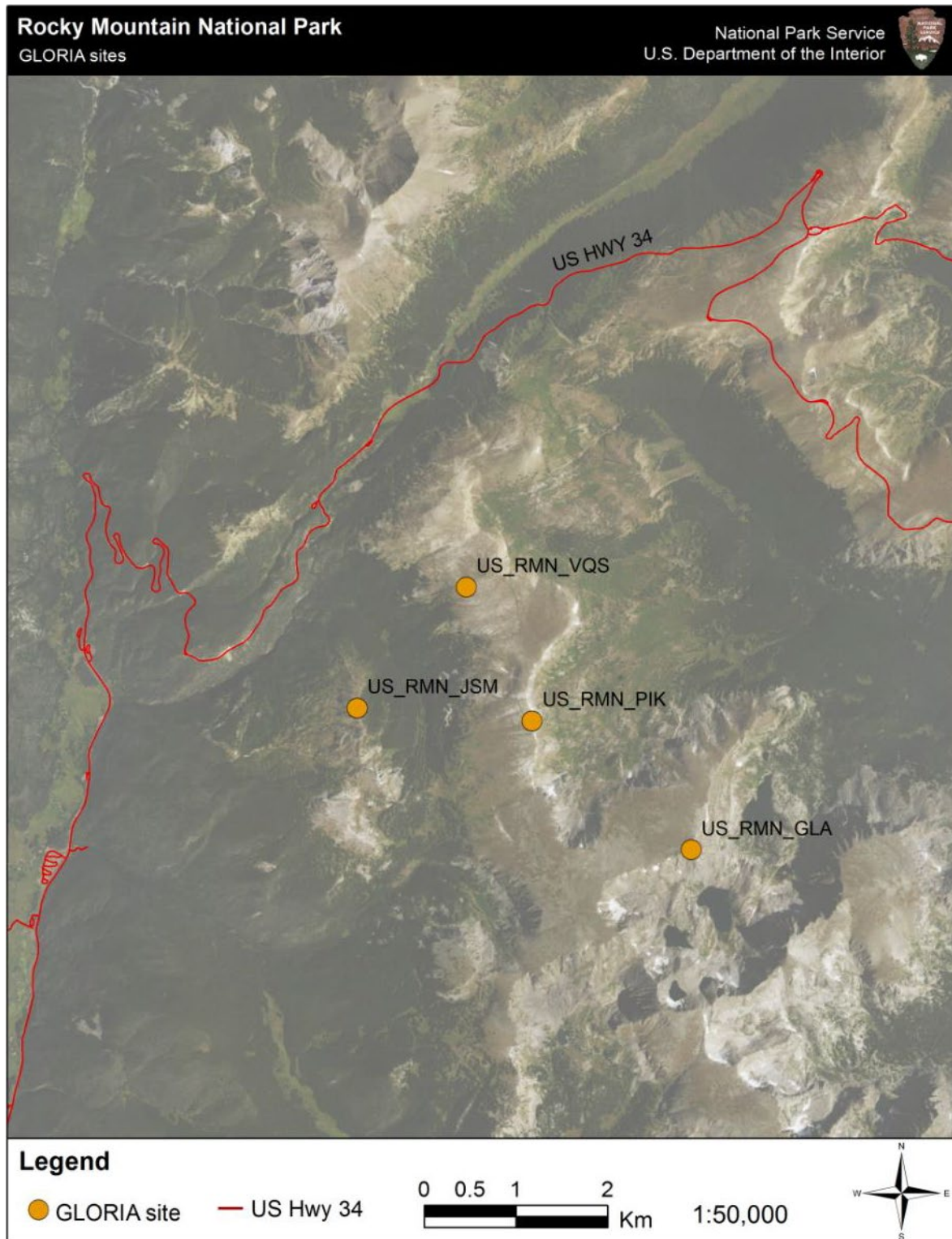


Figure 2. Locations of the four GLORIA peaks in Rocky Mountain National Park. NPS

Table 1. Name, location, elevation, and vegetation zone of the four alpine sites within the target region of ROMO.

GLORIA Summit code	Summit name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Vegetation Zone
GLA	Shoulder of Mount Ida	40.380617	-105.770072	3,862	Upper alpine
PIK	Unnamed	40.392956	-105.790538	3,715	Lower/upper alpine
VQS	Unnamed	40.406275	-105.799238	3,623	Lower alpine
JSM	Jackstraw	40.394304	-105.813083	3,520	Lower alpine/subalpine ecotone

Field Sampling

According to the Lake Irene SNOTEL site, maximum temperatures in 2019 were similar to those in 2024. The most notable differences are in snow depth over the summer. In 2019, there was slightly more snowpack, along with a spike in June, which could've skewed some of the species identified then towards earlier-season species versus some of the later-blooming species like gentians and some members of the *Asteraceae* family. This was likely not the case in the 2024 sampling. Several new species were added to the GLORIA database in 2024. Previously, the only *Antennaria* species to be called on the peaks was *Antennaria media*, but the crew identified three additional species on the peaks, which may have been overlooked in years past. The complete list for all species added to the GLORIA species pool for Rocky Mountain National Park has been recorded in a document maintained by the Rocky Mountain Network.

The CNHP crew sampled all 4 summits comprising the ROMO GLORIA site over the course of three 4-to-5-day long hitches. 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 and cache gear.
2. Establish cardinal directions using a compass declinated to 8 degrees east; find corners of quadrat clusters and flag "no-walk" areas in these locations.
3. One team would begin taking overview photos 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 3 x 3 m vegetation quadrats and would be joined by the first team when their tasks were completed.
4. Once the entire crew was finished with the above tasks, crew members would split up to work on the 10 x 10 m vegetation plots.

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 2024. VQS was sampled first, as it is the easiest peak to access from the Milner Pass Trailhead. JSM was set up and started next, to complete later, with permission from the park. Then, GLA was sampled afterward, because it was the most challenging peak to sample in previous years, and the crew wanted to leave plenty of time to accommodate unexpected weather events.

Both GLA and JSM were accessed primarily via a backcountry campsite, with one site visit to complete remaining JSM plots from a parking pull-off on Trail Ridge Road. PIK was sampled last, over the course of two days on the third week of sampling. In 2024, ROMN provided the crew with species lists for the first time, despite this being contrary to GLORIA recommendations. Species lists allowed the crew to make more informed decisions on whether plants had been misidentified in past

years when adding new species occurrences. The species lists did not include covers and were not relied on to ID, they were simply used to aid in avoiding calling the same plants differently across sampling years. It is recommended to provide crews with lists again in future sampling events.

Vision Quest

The crew took a total of three days in 2024, like in 2019 (compared with four days for the 2014 crew) to sample Vision Quest (VQS). On Day 1, the seven-person CNHP crew was joined by Sarah Marshall, five ROMN staff, and two NPS staff for a total of 15 people. On Day 2, the CNHP crew was accompanied by Sarah Marshall for the first half of the day, and on Day 3, the seven-person CNHP crew completed the peak. The first day was mostly a calibration day, to ensure that all 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 (Figure 3).



Figure 3. Grant Musgrave, Ed Brett, and Clark Hollenberg set up the 10 x 10 m plot on the western aspect of VQS. *NPS/Bodie Spinner*

Site Access and Set-up

VQS is located approximately 5 km up the trail following the Continental Divide at Milner Pass. It took about 1.25 to 1.5 hours to hike up to the summit of VQS carrying field gear (in addition to the 20-minute drive from camp, the total travel time was about 1.5 to 1.75 hours). While surveying VQS, the weather held up for the most part. Only on the third day of sampling did the crew face any afternoon weather. Tree line is approximately 0.75 km from VQS following the trail or 0.5 km straight down the mountain (not required in 2019 or 2024), and it takes approximately 45 minutes to reach the trailhead.

The crew (CNHP and NPS staff and interns) used VQS as a calibration peak, including site set-up, to ensure consistency in plant ID and plot sampling across researchers. The crew did not encounter any difficulties (such as missing plot markers, among other issues) in setting up VQS.

Observations and Sampling Errors

The crew was able to easily locate all monuments for the 3 x 3 m tape quadrats and the high summit point (HSP); however, there are no monuments for the cardinal directions at the 10-meter lower summit area demarcation, those corners are set up using previous measurements. All temperature loggers were collected and replaced in 2023 by a ROMN crew, so the field crew in 2024 did not check the tidbit loggers.

Some initial errors in cover estimates on the VQS peak were potentially due to the learning curve of a crew comprised entirely of members who had no previous experience with the GLORIA protocol. Despite the training day at Ute Trailhead and previous crew lead Sarah Marshall joining for calibration, harmonizing crew cover estimates was challenging. 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, to avoid interrupting 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.

Glacier

Glacier (GLA) was the most difficult peak to survey due to its remote location and steep overland access, exposure to thunderstorms, an approximately 2.5 km distance from summit to tree line, difficulty locating the plot markers (and in some cases not finding them), steep (class III/IV) terrain on the south and east slopes, and unpredictable weather patterns.

Site Access and Set-up

The crew accessed GLA from the backcountry site, Jackstraw Lower, traveling through the backcountry over steep terrain and scree fields for approximately 2 hours to reach the site (Figure 4). GLA can be accessed via the same trail used to reach VQS and PIK, but this route is approximately 10 km one way and takes around 3.5 hours.



Figure 4. The crew bushwhacks up the side of the continental divide on the approach to GLA. *NPS/Clark Hollenberg*

Set-up for GLA was the most time-consuming, even with the experience of setting up the previous site. As with the 2014 crew, photographs from the location of temperature loggers and other past plot photos, as well as site sketches, were the most helpful in locating monuments. The 10-meter points on the east and south sides are located on very steep slopes, and crew member comfort may vary depending on level of mountain experience (Figure 5).



Figure 5. The steep terrain on the south and east aspects of GLA presented challenges for site setup. The crew worked to align the site as closely as possible with historical photos. *NPS/Erin Eastman*

When sampling, take extra safety precautions, such as avoiding having crew members walk above anyone else below, to avoid rockfall danger. In 2019, the crew surveyed plants as far down the slopes as we felt comfortable and safe (e.g., solid rock, minimal to no exposure in the event of a fall). Given some ambiguity in the location of the 5 meter and 10 meter delineations on east and south scree slopes, the crew attempted to replicate the location of photos from 2014 for consistency (which replicated photos from prior sampling events as well).

On the south side of the peak, the crew was unable to locate a monument for the S11 corner. The other corners were marked with nails and washers, which were harder to find, and the 2024 crew was only able to find one nail and washer (S31). The crew relied on the other nail, past photos, and the quadrat grid to replicate the 1 x 1 m sampling location as accurately as possible. It is not clear whether monuments were ever installed in some of the corners, due to the presence of large boulders in monument locations.

In future years, crews could be supplied with a metal detector to attempt to find these nails or monuments and with equipment to install/reinstall any, if needed. Alternatively, check the permit and

ask the park for permission to mark a small 'X' on the large rocks in place of a monument as defined in the GLORIA SOP. An additional challenge at several of these plots is that the quadrat frame does not lie flat; crews must use their best judgment to determine which hits are in and out of the frame when it rests several feet above the ground. Despite these challenges, the crew felt they were able to replicate the sampling locations reasonably well.

Observations and Sampling Errors

As in previous sampling efforts, only the north and west 10 x 10 m plots were sampled due to unsafe working conditions on the south and east sides (see GLORIA manual section 5.3.1). Sampling was challenging in the east summit area section (SAS) due to abrupt topographic changes and being on the edge of a steep scree/boulder field. In the south and east SAS especially, some species may not have been detected due to safety concerns about traversing certain parts of the plot. In past years, crews were chased off the peak due to inclement weather. In 2024, the crew was fortunate to have good weather, so this was likely not a source of error, as it may have been in previous sampling efforts.

Jackstraw Mountain

Sampling Jackstraw Mountain (JSM) was broken up over a few days and two separate hitches. The crew took advantage of the good weather on the day of hiking into the backcountry site, then hiked up to JSM to set up and start a species list. Including the first short day of setup on JSM, the crew completed the peak in 3 days. For all three days, the crew generally had great weather. On the third day of sampling, during the third hitch (see Appendix A), a brief storm sent the crew to the trees nearby for cover, but after 30 to 45 minutes, the crew was able to return to the peak and safely finish surveying (Figure 6). Mosquitoes were not an issue for the crew in 2024, but in 2019, the crew noted that there were many mosquitoes.



Figure 6. Windy conditions on Jackstraw Mountain made measuring and flagging the 5-meter and 10-meter SASs challenging. *NPS/Clark Hollenberg*

Site Access and Set-up

The hike to JSM is challenging due to rough terrain and backcountry travel. It is, however, the lowest peak, which makes the trek to tree line much easier (about 3 minutes). There are no trails leading to JSM, so backcountry travel is necessary to reach the peak.

The 2024 crew took a few different routes, similar to how the 2014 and 2019 crews approached the peak. Backcountry access required the crew to hike from the backcountry campsite at Jackstraw Lower up the drainage, over a small saddle, and then head west toward the peak, following game trails. There were many downed trees, and some backtracking was required to find the safest route.

For front-country access, the crew parked at the Lake Irene trailhead (about a 15-minute drive from Timber Creek campground) and hiked the most direct route to Jackstraw. For only a 1.5-mile hike, it took the crew approximately an hour to ascend, since there were so many downed trees.

With information from past years, it's understood that there are no quick ways to approach JSM from the front or backcountry. It was noted in 2019 that there were more downed trees along the access

routes to JSM than there were in 2014. While no one on the 2024 crew sampled in 2019 to make a comparison between the two years, there was still a lot of downed timber, which made access slow and difficult from the front and backcountry access routes.

Observations and Sampling Errors

As JSM is the lowest peak, there were several new plant species to familiarize ourselves with, which added some time and extra keying during the first day. There were several unknown *Carex* species that were collected and assigned numbers (e.g. *Carex* #4). All crew members were informed of the different *Carex* species, how to identify the differences, and their assigned numbers. The two primary botanists checked in with teams working on the 10 x 10 LPI (line-point intercept) and the 3 x 3 m grids on the species, but there are still likely some errors in the data.

In 2019, orange hawkweed (*Hieracium aurantiacum*), a noxious weed in Colorado, was recorded as 'scattered' in the SAS of the North (with "check" written next to it), East, and South aspects of the peak. In 2024, the crew specifically spent time looking for the plant, but did not find it. It's worth noting that in future sampling efforts, crews should be aware that it was previously recorded, and it's unclear whether it was a mis-ID or whether the 2024 crew just didn't happen to find it.

ROMO park staff have requested that if crews find this (or any noxious weed) again, photos, samples, and exact locations be collected, and the park be informed as soon as possible. It is of great interest to the park if there is a noxious weed growing in an alpine environment.

Pika

The full CNHP field crew was able to sample Pika (PIK) in two days (Figure 7). Both days, the crew descended in the early afternoon due to incoming storms. The crew was able to work efficiently, since all the teams were dialed in on site setup and plant ID. All monuments were located and in place.



Figure 7. The view looking east from PIK, with snow still visible on the eastern aspect of the peak during sampling. *NPS/Lauren Laughlin*

Site Access and Set-up

Similar to VQS, PIK can be reached by the trail following the Continental Divide at Milner Pass which is, on average, a 20-minute drive from the Timber Creek campground. The three-mile hike to PIK takes approximately 1.75 hours up, and 1 hour back to the trailhead. The distance to tree line is approximately 1.5 km along the trail and 0.75 km bushwhacking down steep, rocky slopes. In 2024, the crew did not need to make any rapid retreats to tree line, despite incoming storms both days of sampling.

Observations and Sampling Errors

By the time the crew sampled PIK, they had multiple field days of experience with the GLORIA protocol and plant species in the area (Figure 8). 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 VQS and GLA, which helped to greatly reduce the time required for sampling.



Figure 8. The crew completes their sampling on PIK. *NPS/Clark Hollenberg*

Notes for Future Sampling

General Tasks Prior to 2029 GLORIA Sampling Event

1. Most of the old wooden frames are warped and difficult to set up. Prior to the 2024 sampling event, frames were repaired (some of the strings were too tight). Before the next sampling effort, it would be ideal to adjust the tightness of the strings on the existing PVC frames and replace the wooden frames with PVC frames.
2. Consider making a new photo pole that is compatible with the GLORIA manual. We improvised with a trekking pole.
3. Look into the possibility of some data collection being electronic (e.g., photos, setup measurements, a Survey123 for unknown species)
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), as well as the line direction and position of the start line for each of the 10 x 10 m plots from Form 6-S.
5. Follow up with the GLORIA International Team for guidance on litter: in 2024, the crew counted scat, vagrant lichen, and pieces of plant that were dead, but still attached and at a 45-degree angle or less as litter.
6. Review the paper datasheets from GLORIA; the 10 x 10 m sheets do not have much space for writing the species name, nor do they have a designated space to write a confidence rating for species.
7. Update the ROMN Alpine Vegetation Composition Structure and Soils Monitoring Protocol (Ashton et al. 2010) to reflect current field practices and to add an SOP for site revisits. This information is not currently covered in the existing GLORIA or ROMN SOPs.

Logistical Notes for Future Sampling Events

1. Meeting at the Ute Trailhead was a great way to start the first hitch to get everyone acquainted with the alpine plants and some of the GLORIA protocol. Meeting up in Fort Collins ahead of time to familiarize folks with the gear and the protocol might have been helpful but was not necessary for this crew. Using VQS as a learning peak to help everyone feel comfortable with their roles and further their plant ID was also incredibly helpful, since VQS is very straightforward in terms of setup, and is the easiest to access of the four peaks.
2. As a continuation of a note from 2019, the ROMN field coordinator should reserve campsites as early as feasible. This includes front country camping at Timber Creek Campground and backcountry camping in the Rockslide area. If backcountry sites in the vicinity of Mt. Ida are closed, the field coordinator should contact the Research Learning Center to request an exception to camp in the general area. Request a campsite along the western edge of the Timber Creek campground because it has quieter conditions and better sleep prior to early morning departures.

3. The 2024 crew followed the sampling order of peaks that was used in 2019 (VQS, GLA, JSM, PIK, with the exception of heading up to JSM for setup the day before starting GLA), and this order worked very well for the crew. With this order, VQS is an ideal peak to train on, and it leaves lots of wiggle room for sampling GLA, since it's the most challenging to access. JSM was helpful to have some wiggle room on as well since it is challenging to access. Despite being the lowest in elevation, there are no trails leading to the peak, and the route requires lots of bushwhacking and is slow going. JSM also has a lot of new species that were not found on other peaks, so the extra time to familiarize the crew with them was helpful.
4. Having 15 people on VQS for the first day of actual sampling was quite overwhelming, as most people present had never done the protocol before. In the future, it would be better for the first day(s) to be spent training with the primary field crew, so different teams can be assigned, and everyone on the primary crew has time to ask any questions they need. A day incorporating a larger pool of people is a good idea, since more questions and input were circulated. However, during future sampling, it's better for that to not overlap with the primary field crew's training day(s).
5. In past years, it has been specified that the ideal crew size is five to six people. The 2024 crew was seven people, composed of five CNHP employees and two college interns. Seven crew members, with varying levels of botanical skills and field experience, proved to be a useful number, but a crew of five to six people would have worked well, too.
6. Ensure that the crew is clear on visual estimation of top cover versus total cover and is calibrated in estimation up front.
7. Establish a clear unknown plant procedure up front (e.g., number, tape/tag, bag samples by site, ID or press later in the same day as collection), especially for larger crews from mixed agencies and groups.
8. Stress the importance of clear, legible writing on field forms and/or consider digital data collection where possible or more efficient. The 2019 crew experimented with some digital data but found it cumbersome in some areas of the protocol. The 2024 crew only collected with paper data (aside from taking all photos on the crew iPads), though in future sampling efforts, digital data collection could be useful, with paper as a backup. The major drawbacks of digital data include not being able to back the data up while in the field and potentially losing battery on the devices and portable chargers while spending extended periods of time in the backcountry. Additionally, glare can be challenging in the alpine and often requires the brightness of a tablet to be all the way up, which drains the battery much faster.
9. As time passes from site set-up, the GLORIA database plant names have become increasingly different from the latest nomenclature in the *Flora of Colorado* (Ackerfield 2022) used by the 2024 crew. It's helpful to keep a record of ways to crosswalk species for data entry.

10. Check the status of the Timber Creek trail and Rockslide campsite 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 JSM and GLA. In 2024, the crew learned of a wildfire at the mouth of the Big Thompson Canyon when they saw the smoke rising from the top of GLA. The crew utilized the emergency SPOT Device to contact people in service to get updates on the fire. In the future, it would be helpful for whoever is sending the crew weather updates to also check on wildfire updates.
11. The crew had limited cell phone reception on a couple of peaks, which allowed crew members to occasionally check the latest NOAA weather forecast (including forecasted and approaching electrical storms), though the crew did not rely on this. In the front country, when the crew is camping at Timber Creek Campground, service picks up not too far down the road to the west towards Grand Lake, and individuals could get weather forecasts there as well. However, it was helpful to have a designated person out of the field to send a weather forecast the night before so the crew could plan accordingly and know what to expect. As mentioned above, in the future, with worsening fire conditions, this designated person should also keep an eye on wildfire conditions and relay any updates to the crew.

Conclusion

The 2024 ROMO survey crew was able to successfully sample all four GLORIA summits at a rate of approximately 2 days per summit, spread across a total of 13 days including both travel and field work. Since the crew was entirely made up of people who had never done the GLORIA protocol before, things started slowly, but as the crew became more familiar with their roles, the protocol, and the alpine plants, it became much more efficient.

As opposed to the delayed growing season in 2019, the 2024 growing season appeared to follow typical trends. This means the 2024 crew should have been able to detect the species that would typically be observed in July and August.

When analyzing the data for 2024, as well as the data from 2019, it will be important to note that there were several instances where visual estimates for top cover exceeded the cover sum for the 1 m² quadrats (Form 2 in Pauli et al. 2004). 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.

Additionally, there were a few species on a few peaks that were documented in 1 m² plots but were not accounted for in the 0 to 5 m SAS on that particular aspect. Those species were added to the SAS list, and were generally assigned low abundance ranks, since they were not common enough to have been picked up in the SAS.

Any species that were added to the SAS lists out of the field were flagged in the GLORIA database and written on the datasheets in red pen. All findings or changes made during data entry are recorded in a document maintained by the Rocky Mountain Network, which can be referenced at any time in the future when considering decisions made.

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Appendix A: US-RMN 2024 Field Log

Date	Peak	Persons	Activities	Notes
7/22/2024		Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Sarah Marshall, Kati Zybko, Elizabeth Wu, Claire Anderson, Ali Goodrich, Erin Borgman, Dana Witwicki	Meet at the Ute Trailhead off Trail Ridge Road to learn/familiarize plants, practice using the microgrid and pin drops, and answer any initial questions	Leave Fort Collins at 6am to meet at (40.3933217089014, -105.69536096133872) off Trail Ridge Rd at around 8 am.
7/23/2024	VQS	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza, Sarah Marshall, Kati Zybko, Elizabeth Wu, Claire Anderson, Ali Goodrich, Erin Borgman, Dana Witwicki, Jax Maldonado	Roles assigned, protocol reviewed, site set-up, (5) 1 m ² cover plots, (3) SAS, most photos completed	Left Timber Creek campground at 4:45, arrived at Milner Pass at 5:00; arrived at VQS at 6:30. The hike is approximately 2 miles with about 1,050 ft of elevation gain on the hike. Departed VQS around 16:00, since the weather held up all day.
7/24/2024	VQS	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza, Sarah Marshall	(2) 1 m ² cover plots, (1) 10 x 10 m plot, (4) SASs, remaining photos	Left camp around 5:45 to arrive at the trailhead at Milner Pass at 6:00, arriving at the peak at 6:45. Descended at around 16:30, since the weather held up all day
7/25/2024	VQS	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	(9) 1 m ² cover plots, (3) 10 x 10 m plots, (1) SAS; took down camp and headed back to home base for the week	Left camp around 5:30 to arrive at the trailhead at Milner Pass and start hiking at 5:55, arriving at the peak at 6:40. Descended around 15:00 after finishing the peak, due to an incoming storm
7/29/2024	JSM	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Commuted to Timber Lake Trailhead, organized gear, and backpacked into backcountry campsite. Ate lunch and set up camp, and then hiked up to JSM to start site setup for later in the week, (1) SAS	Left Fort Collins at around 5:30 am. After the drive and organizing gear, the crew hit the trail at around 9:30 am. The hike to the basecamp was about 4.5 miles with about 1,841 ft of elevation gain and took the crew about 2 hours to complete. The crew hiked up to JSM at around 13:45 with a 2 mile hike and ~800 ft of elevation gain and descended at 17:00.
7/30/2019	GLA	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Site set-up, (8) SASs, (1) 10 x 10 m plot, most photos completed, (6) 1 m ² cover plots	Departed from basecamp at 5:30 to hike up to GLA. The hike was about 2.9 miles with 1,855 ft of elevation gain and took the crew an hour and 35 minutes to summit. With good weather, the crew stayed at the peak until around 16:30.
7/31/2019	GLA	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	(9) 1 m ² cover plots, (1) 10 x 10 m plot, and remaining photos completed	Departed camp 5:30, arrived at GLA around 7:15. Since the weather cooperated, the crew stayed at the peak and finished surveying, descending around 16:00.

8/1/2024	JSM	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Finish site set-up, (8) 1 m ² cover plots, (7) SASs	Departed from basecamp at 5:40 to continue surveying JSM. Descended around 13:45.
8/2/2024		Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Packed up camp, hiked down to the trailhead and drove home	Departed camp at 8:00 to hike back to Timber Lake Trailhead. The hike down was another 4.5 miles with 137 ft of elevation gain, and took the crew approximately 1.5 hours
8/5/2024	JSM	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Commuted to ROMO, finished JSM; (8) 1 m ² cover plots, (4) 10 x 10 m plots	Left Fort Collins at 6:00 am and met at the Lake Irene Trailhead. Due to a fire, 34 and the Big Thompson Canyon were closed, and the crew had to detour and drive on 36 through Lyons to get up to Estes. The hike up to JSM was about 1.5 miles with 1,162 ft of elevation gain, and took the crew about an hour
8/6/2024	PIK	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Set up PIK, (8) SAS, (4) 1 m ² cover plots, most photos completed	Left camp at around 6:30 am to head to Milner Pass. The hike to PIK is approximately 3 miles with 1,400 ft of elevation gain and took the crew about an hour and 15 minutes. Descended around 13:30 due to an incoming storm
8/7/2024	PIK	Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	(4) 10 x 10 m plots, (12) 1 m ² cover plots, and remaining photos completed	The crew left camp at 5:45 am for Milner Pass and hit the trail at 6:00. Arrived at the peak at around 7:15, and descended around 14:00 after finishing, to avoid an incoming storm
8/8/2024		Lauren Laughlin, Ed Brett, Clark Hollenberg, Grant Musgrave, Bodie Spinner, Erin Eastman, Sam Carles Pedroza	Pack up camp and head back to Fort Collins	