



Alpine vegetation composition and structure monitoring for Rocky Mountain National Park

2019 Trip Report



ON THE COVER

Old man of the mountain (*Hymenoxys grandiflora*) growing along the flanks of Mount Ida, on the Western border of Rocky Mountain National Park, July 2019.

Photograph by Sarah Marshall.

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Executive Summary

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 PIK, VQS and 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 10cm, 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 10mx10m frequency plots and 10mx10m 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 10x10m frequency plots were not completed in 2010 due to lack of time. The 10mx10m 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 10x10m 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. Soil samples should be collected again in 2024.

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 and 2019, 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, any irregularities or errors in surveying, and logistical details that may be beneficial for 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 Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson, Kati Zybko, Casey Duncan, and Clemence Roulotte. Special thanks also go out to the staff of Rocky Mountain National Park, particularly Scott Esser, 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 2019 all four sentinel sites were sampled following the GLORIA protocol with the adapted ROMN protocol though anthropogenic factors using the Disturbance Index and the California Rapid Assessment Method for Wetlands.

In 2019, a field crew from CNHP and NPS sampled all four summits within the Rocky Mountain National Park (ROMO) GLORIA site over the course of several 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 site, the field crew (Jimmy Turowsky, John Dietrich, Teru Funabashi, and Kyle Jackson) met for a half day of office and field training at the CNHP office with Sarah Marshall (CNHP project lead) and Erin Borgman (ROMN) in order to familiarize everyone with survey and safety protocols, and the purpose and need of using the GLORIA research methods. The group visited a small hill on the Colorado State University campus to become familiar with GLORIA methodology and practice setting up the 3m x 3m quadrat clusters, the 1m² quadrats, the summit area sections and the 10m x 10m square line-intercept plots.

Given the frequency of lightning storms during the 2014 sampling event, 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 dish washing station, a large bear-safe trash and recycling bin and several bathrooms with electricity and running water. The crew was able to request a campsite along the

western edge of the campground during the third week, which afforded quieter conditions and better sleep prior to early morning departures.

In order to access GLA and part of JSM during the second week of surveying, the crew camped at a backcountry site in the vicinity of the Rockslide campsites, located approximately 5 miles up the Timber Lake trail. The designated Rockslide campsite was closed by RMNP staff due to standing dead tree hazards, so the crew was asked to camp at a location that would not be visible from the Timber Lake trail, sufficiently far from sensitive vegetation areas. To secure park permission to camp out of bounds, the ROMN field coordinator submitted a request with location and dates of proposed camping and justification to the Continental Divide Research Learning Center in May. Research Learning Center staff coordinated with the district ranger to secure approval with the understanding that the crew follow specific guidelines, such as being out of site of any potential visitors to the area and leaving no trace of camp. After an arduous trek up a slope covered in downed timber, and bypassing a flat area with abundant moose and elk scat, the crew found a large flat site that was bordered by forest and adjacent to an open meadow approximately 1,000 feet northeast of the main Rockslide campsites (13T 431837E 4470466N, WGS84). The crew was able to filter water from a stream to the north of camp, and borrowed bear-safe food barrels from RMNP (included with the backcountry pass for the campsite free of charge). It is worth noting that the crew encountered several moose en route to camp (which necessitated a brief stop on the Timber Lake trail on the way to camp) and at camp, including 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 2019, the route through the slide area was passable, but still steep, covered in fallen timber, and required climbing over and under several logs with full packs.

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.

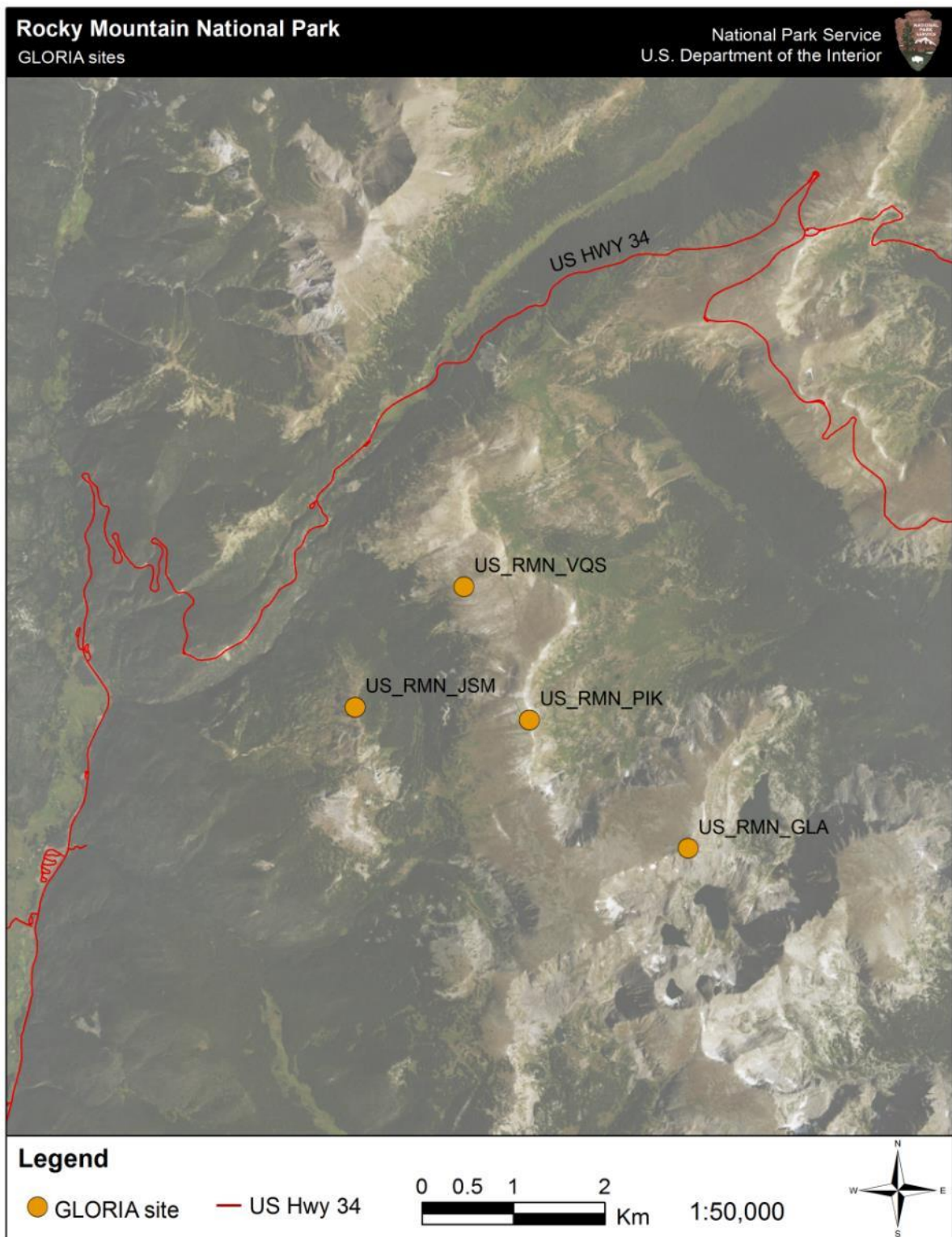


Figure 1. Locations of the four GLORIA peaks in Rocky Mountain National Park.

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

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

GLORIA Summit code	Summit name	Elevation (m)	Vegetation Zone
GLA	Shoulder of Mount Ida	3862	Upper alpine
PIK	Unnamed	3715	Lower/upper alpine
VQS	Unnamed	3623	Lower alpine
JSM	Jackstraw	3520	Lower alpine/subalpine ecotone

Field Sampling

The 2019 alpine growing season was delayed slightly in ROMO due to an above-average year for snowpack and late snowmelt. In general, this did not appear to hinder detection of key species, but occasionally made identification more challenging and may have slightly skewed detected plants toward earlier-season species vs. some of the later-blooming species like gentians and some members of the *Asteraceae* family.

The CNHP crew sampled all 4 summits comprising the ROMO GLORIA site over the course of several weeks. 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.
4. Once the entire crew was finished with the above tasks, crew members would split up to work on the 10m x 10m 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 2019. VQS was sampled first, as it is the easiest peak to access from the Milner Pass Trailhead. GLA was sampled next, because it was the most challenging peak to sample in 2014 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, with a half-day of set-up with 2 crew members followed by a full day with a large crew (7 CNHP and NPS staff and interns).

VQS

The crew took a total of 3 days (compared with 4 days for the 2014 crew) to sample VQS, including a larger crew with 3-4 NPS staff (including 1 intern) joining the 5-person CNHP on Day 1 and 2, and only the CNHP crew on Day 3. 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.

Site Access and Set-up

VQS is located approximately 5 km up the trail following the Continental Divide at Milner Pass. It took about 1.25-1.5 hours to hike up to the summit of VQS carrying field gear (in addition to the 20 minute drive from camp travel time was about 1.5-1.75 hours). While surveying VQS, the crew was forced to either return to tree line or the trailhead in the early afternoon on each sampling date due to the threat of electrical storms. Tree line is approximately 0.75 km from VQS following the trail or 0.5 km straight down the mountain (not required in 2019) 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 (missing plot markers, etc.) in setting up VQS.



Kyle Jackson and Terutaka Funabashi collecting plant cover data in a 10m x 10m plot on VQS in Rocky Mountain National Park (July, 2019; photographed by Sarah Marshall).

Observations and Sampling Errors

The crew was able to easily locate all monuments and temperature loggers. The north quadrat cluster had two temperature loggers, instead of the usual one, as part of an experiment to test the longevity of the Tidbit loggers. Both loggers were collected, but only one logger was replaced.

Some initial errors in cover estimates on the VQS peak were potentially due to the experiential learning curve of a crew primarily comprised of 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.

In reviewing the data forms for VQS, 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.

An additional challenge in 2019 was that the field visit followed an above-average year for snowpack with later snowmelt than is typical in this region. As a result, it is likely that the crew caught more early-season species, such as *Draba* spp., but had a greater portion of graminoids and some later-blooming members of the *Asteraceae* family that were not in their peak blooming state. 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. Species with lower confidence at the genus or species level were flagged on each data form using appropriate codes. This effect was more pronounced at VQS than all other summits.

GLA

GLA was the most difficult peak to survey due to its remote location and steep overland access, exposure to thunderstorms with 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. The full CNHP crew (5 members) sampled most of the site in one day before being chased off the summit by a sudden thunderstorm, and a smaller team of three returned the following day to complete several remaining plots.

Site Access and Set-up

The crew accessed GLA from the dispersed campsite near the closed Rockslide campground, traveling through the backcountry over steep terrain and scree fields for approximately 2 hours to reach the site. 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.

Set-up for GLA was the most time consuming, even with the experience of setting up the previous site. As with the 2014 crew, we found photographs from the location of temperature loggers and other past plot photos to be the most helpful in locating monuments. The 10m 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. When sampling, take extra safety precautions such as avoiding having crew members walk above anyone else below, to avoid rock fall 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

5m and 10m 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 north side of the peak, the crew was unable to locate monuments for 3 of the quadrat corners (N 1,3; N 3,1; N 3,3), and had to rely on using the quadrat grid, established sampling points, and photos from 2014 to replicate sampling locations as accurately as possible. It is not clear whether monuments were ever installed in some of these locations, 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 monuments and equipment to install/reinstall any, if needed. An additional challenge at several of these plots is that the quadrat frame does not lay flat; crews must use their best judgement 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.



Sunrise view from the ridgeline leading to GLA in Rocky Mountain National Park (August, 2019; photographed by Sarah Marshall)

Observations and Sampling Errors

As in previous sampling efforts, only the north and west 10mx10m 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 5m summit area section (SAS) due to abrupt topographic changes and being on the edge of a steep scree/boulder field. All temperature loggers were relatively easy to find and replace once plots were located. There was an additional temperature

logger located in the south quadrat cluster, testing the longevity of Tidbit loggers; it was removed and not replaced.

Some errors may have resulted from being rushed in completing survey work due to inclement weather near the end of the first sampling date. There was also a small amount of snow still left in the west 10m SAS, and several areas that had obvious recent snow melt near the cliff face, which may have affected the number of species detected in this area.

In reviewing the data forms for GLA, 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.

JSM

The JSM peak took 2 days with 2-5 people, and a third partial day with 2 people to complete all field work. The first 2 sampling days had early afternoon rain and thunderstorms, which limited the length of field days. This site can be saved for days with scattered showers, where crews can sample during good weather windows and have tree cover during brief storms. The 2019 crew was also able to send a smaller team back to complete several remaining plots and have the rest of the crew begin set-up for the next site. It is worth noting that JSM had many mosquitoes in 2019.

Site Access and Set-up

The hike in to JSM is challenging due to rough terrain and backcountry travel. It is, however, the lowest peak making 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. We took two different routes, similar to the 2014 crew, beginning from a pull-off near the Lake Irene trailhead (about a 15 minute drive from Timber Creek campground) and one route from the Rockslide-area dispersed backcountry camp site (Appendix 2, Figure 6). Route 3 on Figure 6 is approximately 2 km from the Rockslide campground and cuts through a wet meadow before climbing over a small saddle that will come out on the southwest side of JSM. From here, several game trails can be picked up along the south side of the mountain which lead to the JSM site. Our crew stayed low on this side of the mountain in order to avoid steep boulder fields. Route 1 on Figure 6 is approximately 2.25 km and begins at a small road-side pullout along Highway 34/Trail Ridge Road. The trail drops steeply down towards and across Beaver Creek. This route then ascends and descends the next immediate peaklet before crossing a tributary to Beaver Creek. After crossing the tributary, this route then climbs the north edge of JSM steadily until reaching the site. Route 2 is approximately 2.7 km and begins at the parking lot for the Lake Irene trailhead.

This route follows Beaver Creek around the peaklet that Route 1 climbs over which includes more side slope traversing and wetland navigation but cuts out the climb over the hillside. After navigating around the peaklet, Route 2 crosses the same tributary as route 1 and roughly follows the same route after the stream crossing. Both Route 1 and 2 took approximately two hours to reach the JSM summit and the route from the Rockslide-area campsite took approximately one hour to reach JSM. It is worth noting that there was more downed timber along the access routes to JSM in 2019 than there was in 2014, making overland travel more challenging.



John Dietrich and Terutaka Funabashi surveying the cluster quadrat on JSM in Rocky Mountain National Park (August, 2019; photographed by Sarah Marshall).

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. All temperature loggers were relatively easy to find and replace. There was an additional temperature logger located in the South quadrat cluster, which the crew noted on the temperature logger data form. The additional logger was removed and not replaced.

Some graminoids were hard to ID at JSM due to their immature state, and crews used form, nearby similar (more mature) plants, ligule characteristics, and other features to ID as needed. Where confidence was low, crews used the cf. column on the data forms. Several isolated areas

appeared to have held snow for a longer period into the growing season (e.g., southeast part of the 10m east SAS).

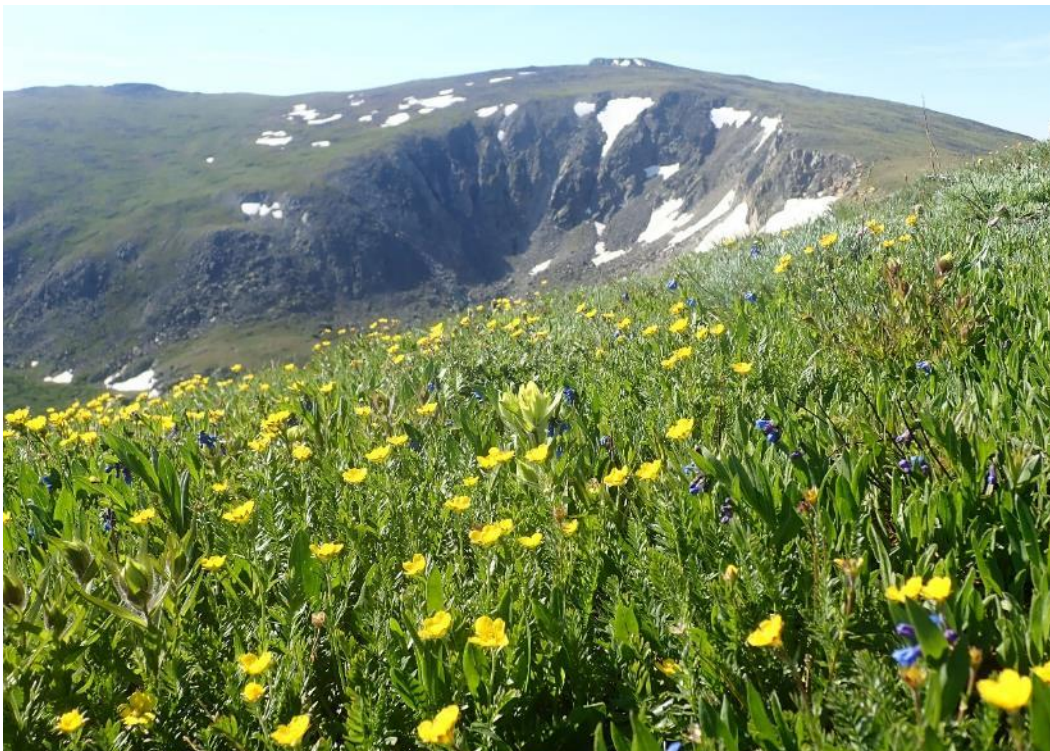
In reviewing the data forms for JSM, there were several instances where visual estimates for top cover exceeded the cover sum for the 1m² quadrats (Form 2). In order to address this error, we reviewed quadrat photos in the office to check and occasionally re-assess cover values for top cover of surface 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.

PIK

The full crew, with 4 CNHP and 3 NPS staff and interns, was able to complete most sampling for PIK in a single day after a team of 2 set up the site on the previous day. We were able to accomplish this due to excellent weather, and clear skies until late afternoon.

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 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.



Lush vegetation on PIK after an above-average year for snowpack in Rocky Mountain National Park (August, 2019; photographed by Sarah Marshall).

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. 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. All of the temperature loggers were relatively easy to find and replace. One extra logger was found in the west quadrat cluster, and was collected, but not replaced.

Notes for Future Sampling

General Tasks Prior to 2024 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), as well as the line direction and position of the start line for each of the 10m x 10m plots from Form 6-S. 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 half day training on CSU campus was adequate, though the field crew spent additional time at the first field site becoming familiar with the flora. Ideally, training would 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 an easily accessible location to begin learning the plants likely to be encountered in GLORIA plots.
2. 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 remain 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 – it has quieter conditions and better sleep prior to early morning departures.
3. In 2019, we sampled the peaks in a different sequence compared to 2014 (VQS, GLA, JSM, then PIK). This worked well in sampling the closest, easiest-access (mostly on a well-established trail vs. backcountry overland travel) peak first to get the crew calibrated, followed by the most difficult peak (GLA) to allow for enough time to sample with storms. JSM was a good intermediate peak due to its access from either the backcountry site or off the Trail Ridge Road pull-off. PIK worked well as a final peak,

but could also be sampled as the second peak (after VQS) if the crew was able to complete VQS in two days.

4. The crew greatly benefitted from having additional NPS staff join the CNHP crew in 2019, after an initial training and calibration period during the first 2 field days. By the last sampling date, the 7-member crew (including 2 interns) was able to sample an entire summit (PIK) in a single day with good weather. The ideal crew size is 5-6 people, with at least three solid botanists/plant ecologists who can lead quadrats, 10m x 10m plots, 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.
6. Establish a clear unknown plant procedure up front (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.
7. 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 digital data collection, but found that some forms were particularly cumbersome as currently set-up in the data collection app (e.g., 10x10m plots). Test potential data collection improvements prior to the next sampling event in 2024.
8. 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 the 2019 crew. 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 2019 crew also utilized the keys in *Sedges of Colorado* (Wingate 2017) for *Carex* species.
9. 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.
10. The crew had limited cell phone reception on several peaks, which allowed for crew members to occasionally check the latest NOAA weather forecast (including forecasted and approaching electrical storms).

Conclusion

The 2019 ROMO survey crew was able to successfully sample all 4 GLORIA summits at a rate of approximately 2 days per summit, spread across a total of 10 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.

The 2019 alpine growing season was delayed slightly in ROMO due to an above-average year for snowpack and late snowmelt. In general, this did not appear to hinder detection of key species, but occasionally made identification more challenging and may have slightly skewed detected plants toward earlier-season species vs. some of the later-blooming species like gentians and some members of the *Asteraceae* family.

When analyzing the data for 2019, 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-RMN 2019 Field Log

Date	Peak	Persons	Activities	Notes
7/23/2019		Sarah Marshall, Erin Borgman, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	Half day of training at CNHP and commute to Timber Creek campground	2 hour drive to campground
7/24/2019	VQS	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson, Kati Zybko, Casey Duncan, Clemence Roulotte	Site set-up, (3) 1m ² cover plots, (1) SAS, all Tidbit loggers replaced and most photos completed; QC and plant ID at camp	Left Timber Creek campground at 4:45, arrived at Milner Pass at 5:00; arrived at VQS at 6:45. Departed VQS around 13:00 due to incoming storm
7/25/2019	VQS	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson, Kati Zybko, Casey Duncan, Clemence Roulotte, Erin Borgman	(6) 1m ² cover plots, (1) 10mx10m plot, (5) SASs, remaining photos; QC and plant ID at camp	Arrived at VQS at 7:00. Departed VQS around 13:00 due to incoming storm
7/26/2019	VQS	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	(7) 1m ² cover plots, (3) 10mx10m plots, (3) SASs; took down camp and headed back to home base for the week	Departed camp at 6:15, arrived at Milner Pass at 6:45, arrived at VQS at 8:20. Departed VQS at 14:00 due to incoming afternoon thunderstorm
7/29/2019		Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	Commuted to Timber Lake trailhead, organized gear, and backpacked in to dispersed campsite near Rockslide campground	
7/30/2019	GLA	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	Site set-up, (8) SASs, (4) 10mx10m plots, (3) Tidbit loggers replaced, most photos completed, (11.5) 1m ² plots; QC and plant ID at camp	Departed camp at 4:45, arrived at GLA at 6:45, returned abruptly to camp around 15:00 due to a sudden hailstorm and incoming thunderstorm
7/31/2019	GLA	John Dietrich, Teru Funabashi, Kyle Jackson	(4.5) 1m ² cover plots, (1) Tidbit logger replaced, and remaining photos completed	Departed camp 5:00, arrived at GLA around 7:15; met rest of crew at JSM around 10:30
7/31/2019	JSM	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	Site set-up, (2) 1m ² cover plots, (2) SASs	Departed camp at 6:00, arrived arrived at JSM around 7:00, departed JSM around 12:00 due to rainstorm that turned into a thunderstorm later in the day
8/1/2014	JSM	Sarah Marshall, Jimmy Turowsky, John Dietrich, Teru Funabashi, Kyle Jackson	(10) 1m ² cover plots, (6) SASs, (4) 10m x 10m plots	Departed camp at 5:00, arrived at JSM around 6:00, departed JSM around 13:00 due to rainstorm that turned into a thunderstorm later in the day

8/5/2019	JSM	Jimmy Turowsky, John Dietrich	Commute to ROMO, (4) 1m ² cover plots	Arrived at pull-off on Trail Ridge Road around 8:30, arrived at JSM around 9:30. Left JSM around 12:30 to avoid afternoon thunderstorm.
8/5/2019	PIK	Sarah Marshall, Kyle Jackson	Commute to ROMO, set up PIK, (4) Tidbit loggers replaced, (1) SAS	Traveled to ROMO; hiked into PIK (fast and light), arrived at PIK around 10:00; returned to trailhead around 12:30 to avoid afternoon thunderstorm
8/6/2019	PIK	Sarah Marshall, Jimmy Turowsky, John Dietrich, Kyle Jackson, Kati Zybko, Casey Duncan, Clemence Roulotte	(4) 10mx10m plots, (7) SASs, (16) 1m ² cover plots, all photos	Arrived at site around 6:45, completed site and headed back to trailhead around 15:30; camped and then traveled to next field project (non-GLORIA) as part of a larger field hitch on 8/7/2019

Appendix B: US-RMN 2019 Route Map

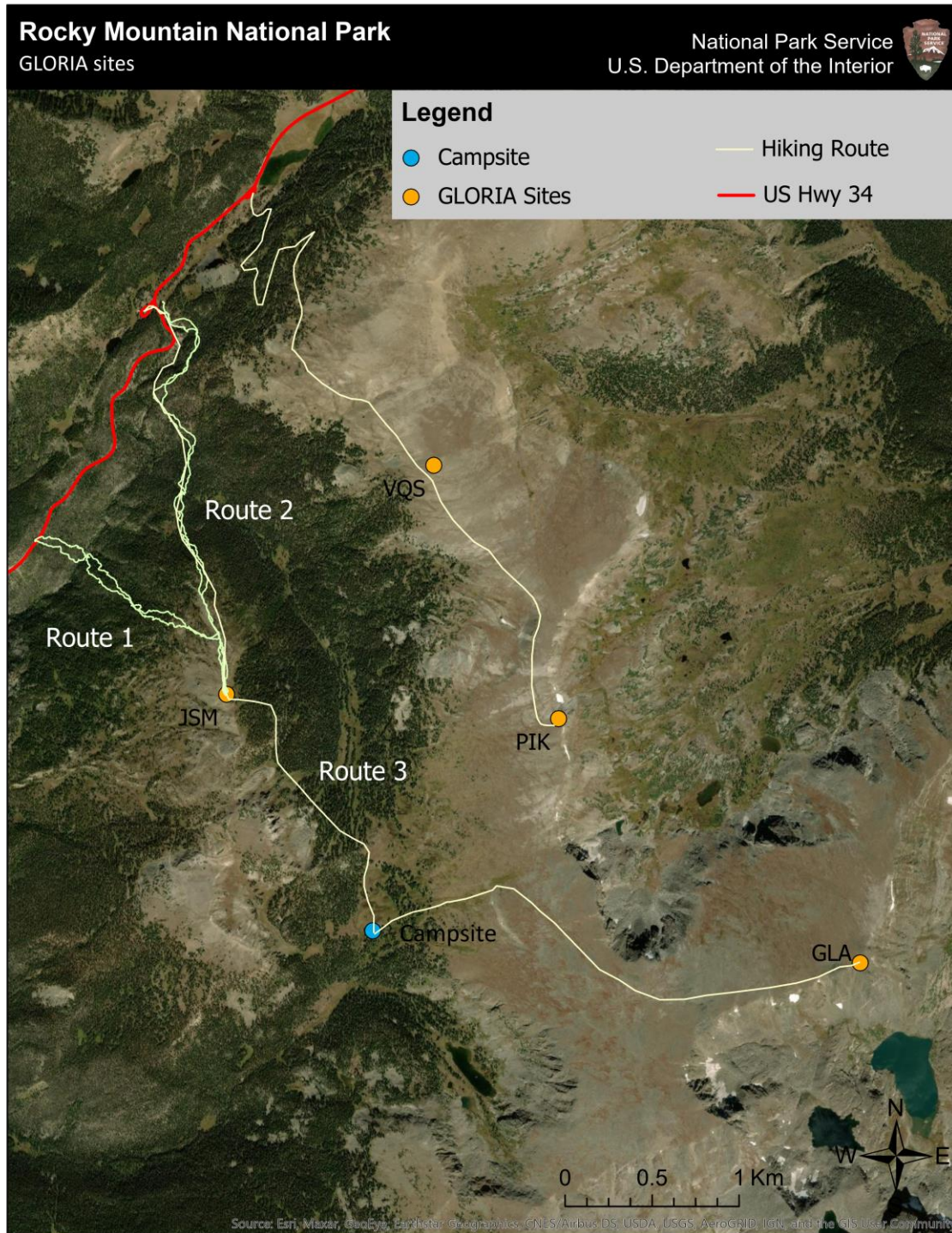


Figure 2. Overview of routes to reach each peak in Rocky Mountain National Park. VQS and PIK were accessed from the Milner Pass Trailhead. JSM was accessed both from the Lake Irene parking area and from the backcountry campsite. GLA was accessed from the backcountry campsite.

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