



# Alpine vegetation composition and structure monitoring for Yellowstone National Park

## *2022 Trip Report*



Looking southeast from Boundary Line Peak, on the eastern border of Yellowstone National Park. Boundary Line Peak is one of four selected GLORIA summits in the Absaroka Mountains of Wyoming.

NPS / TERUTAKA FUNABASHI

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## **2022 Trip Report**

Alexa Armstrong<sup>1</sup>, Terutaka Funabashi<sup>1</sup>

<sup>1</sup> Colorado Natural Heritage Program  
Colorado State University  
1475 Campus Delivery  
Fort Collins, CO 80523

Eliot Rendleman<sup>2</sup>, editor

<sup>2</sup> National Park Service  
Northern Colorado Plateau Network  
2282 W. Resource Blvd.  
Moab, UT 84532

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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 Greater Yellowstone I&M Network (GRYN) identified alpine vegetation composition, structure, and soils as a vital sign that can be used to better understand the condition of park ecosystems (Bingham et al. 2011).

The Yellowstone National Park (YNP) Global Observation Research Initiative in Alpine Environments (GLORIA) alpine monitoring site was established in 2011 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 2011, an alpine monitoring site was established at YNP following the GLORIA protocol (Kuhn et al. 2015). GLORIA sentinel sites were established at the summits of four unnamed peaks—hereafter referred to as Boundary Line Peak (BLP), Snow Pipit Peak (SPP), Stone Crop Peak (SCP), and Wolf Scat Peak (WSP)—in the upper Lamar River area, northeast of Lamar Mountain, WY. The peaks ranged in elevation from 3,122 to 3,195 meters. The established sentinel sites included sixteen 1-m<sup>2</sup> quadrat clusters per peak and eight summit area sections per peak. After site establishment, vegetation characteristics were recorded, temperature loggers were buried in the center of each cluster at a depth of 10 cm, comprehensive photographs were taken at all sites, soil was collected at each summit area section for soil chemistry and texture analysis, and natural and anthropogenic disturbance were described. The sites were established and sampled by a Colorado Natural Heritage Program (CNHP) field crew over three visits for a total of 21 days.
- GRYN and CNHP staff, recognizing the concern for battery life, replaced temperature loggers in September 2013, in September 2015, and on July 20 and 21, 2016. The logger on the south aspect of SCP was not found during the 2013 visit, and the east aspect logger on SPP was not found in 2015. The loggers on the south and west aspects of WSP were left in place in 2013 to test battery duration. Periods without temperature data are as follows: SCP south aspect from August 2011 to September 2013 (logger not relocated), SPP east aspect from September 2013 to September 2015 (logger not relocated), WSP south aspect from February 2015 to September 2015 (battery failure), and WSP west aspect from December 2013 to September 2015 (battery failure).
- In late July 2016, YNP sentinel sites were relocated and sampled for a second time according to the GLORIA protocol (Tortorelli et al., 2019). Vascular plant surveys were completed on all 1-m<sup>2</sup> quadrat clusters and summit area sections. The crew collected soil samples from all aspects of the four peaks, as was done in the initial sampling. This sampling event was completed by a field crew of six people (two botanists and two interns from CNHP and two Yellowstone National Park botanists) over an eight-day

period. Temperature loggers were located and replaced two days prior to the sample visit by GRYN and YNP staff.

- In August 2021, temperature loggers were replaced by Kristin Legg and Ann Rodman. A full sample visit did not occur due to fire and compromised air quality.
- In early August 2022, YNP sentinel sites were relocated and sampled for a third time according to the GLORIA protocol. The sampling occurred over an eight-day field hitch, including travel. Vascular plant surveys were completed on all 1-m<sup>2</sup> quadrat clusters and summit area sections. Temperature loggers were not replaced at this time. Soil samples were not collected, as they were collected in both 2011 and 2016.

GLORIA sites are typically surveyed in five-year intervals for vegetation composition, structure, and soil temperature. Site establishment and baseline monitoring were carried out in 2011, with a subsequent full sample visit in 2016. Due to environmental challenges of fire and compromised air quality during the 2021 field season, the third sample visit did not occur until 2022.

The purpose of this report is to outline the basic timeline of the 2022 sampling, any irregularities or errors in surveying, and logistical details that may be beneficial for future survey crews (Appendix A).

## **Acknowledgments**

We would like to thank all who assisted with preparation, training, field work, and data management and provided the knowledge and insight necessary for the GLORIA study. We want to acknowledge the hard work of the 2011 GLORIA team that established the YNP GLORIA site. We are extremely grateful for the 2022 field crew: Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, and Abigail Rios with CNHP; and Emily Griffoul and Olivia Sena of Betty Ford Alpine Gardens. Special thanks to Sarah Marshall and Andrea Schuhmann of CNHP and Kristin Legg, Heidi Anderson, Ann Rodman, and Erin Borgman of NPS for their help with project planning and coordination. Many thanks to Meade and Andrea Dominick and the staff of 7D Ranch, who packed in field supplies to the remote backcountry site.

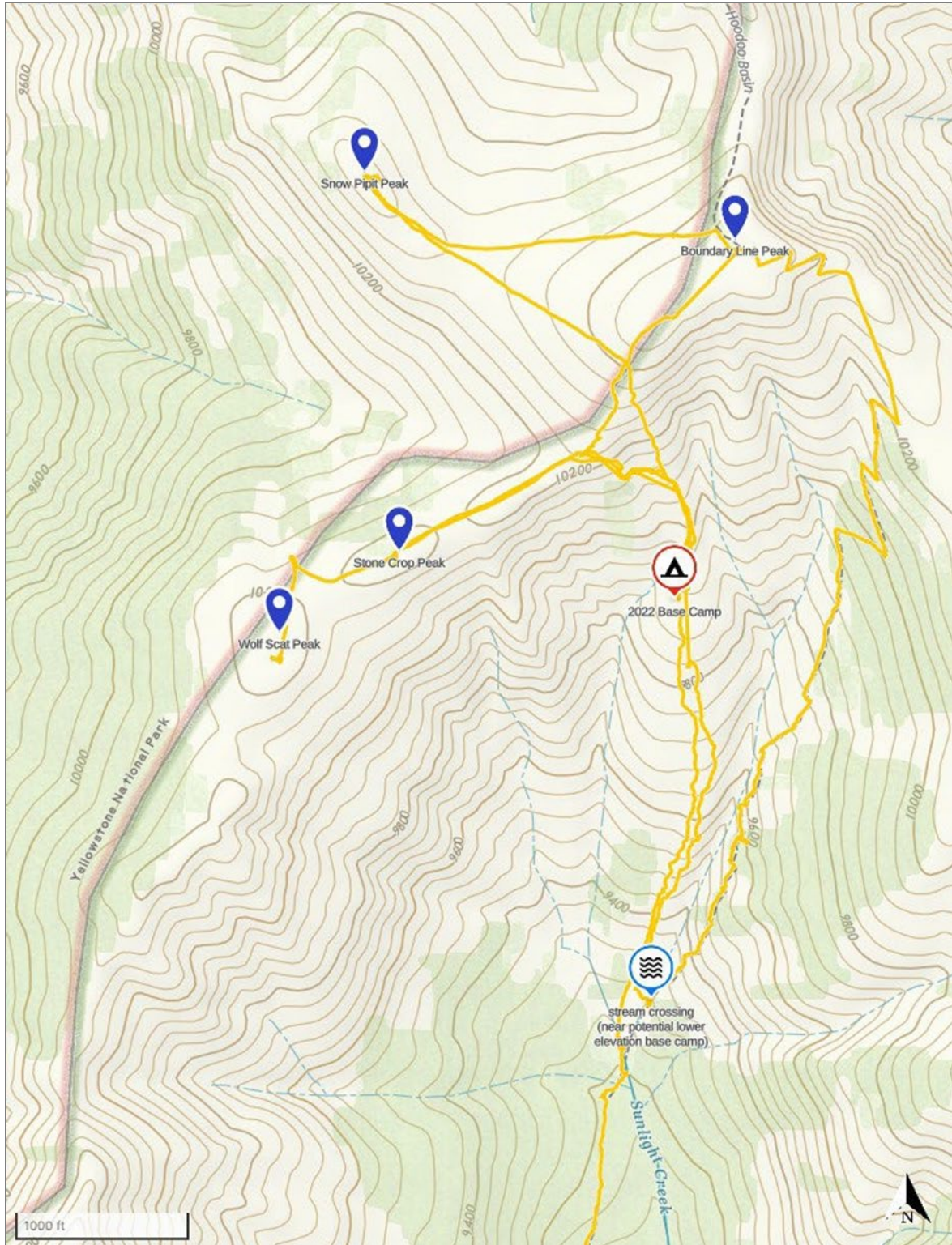
# Introduction

The Rocky Mountain I&M Network (ROMN) adapted an alpine monitoring protocol from 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, Ashton et al. 2010). 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 YNP GLORIA monitoring site is in the Absaroka Range of the Central Rocky Mountains in northwest Wyoming. Plot installation and the initial sampling of the four sentinel sites (summits) took place in 2011. In 2016 and 2022, all four sentinel sites were resampled following the same GLORIA protocol, with the addition of the adapted ROMN protocol for anthropogenic factors using the Disturbance Index.

During the 2022 field visit, a field crew from CNHP and Betty Ford Alpine Gardens completed resampling of all four summits within Yellowstone National Park over the course of eight days (Figure 1, Table 1, Figures 10–11 in Appendix B). The following summary outlines key information about how the site was sampled and lessons learned that may be applied to future sampling events.

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

<b>GLORIA Summit Code</b>	<b>Summit Name</b>	<b>Latitude (decimal degrees)</b>	<b>Longitude (decimal degrees)</b>	<b>Elevation (m)</b>	<b>Vegetation Zone</b>
BLP	Unnamed (referred to as Boundary Line Peak)	44.700184	-109.826731	3,195	lower alpine
SCP	Unnamed (referred to as Stone Crop Peak)	44.695765	-109.834566	3,122	lower alpine
SPP	Unnamed (referred to as Snow Pipit Peak)	44.701613	-109.835067	3,169	lower alpine
WSP	Unnamed (referred to as Wolf Scat Peak)	44.694275	-109.837219	3,124	lower alpine



**Figure 1.** Locations of the four peaks in Yellowstone National Park, Wyoming, and overview of 2022 access routes to reach each summit from base camp. Hiking routes are shown as solid yellow line. NPS

## **Training**

Prior to conducting field surveys at the YNP site, the field crew (Terutaka Funabashi, Emma Jordan, Brennan Kurosad, and Abigail Rios [CNHP] and Emily Griffoul and Olivia Sena [Betty Ford Alpine Gardens]) coordinated remotely with Alexa Armstrong (CNHP, YNP project lead) and Sarah Marshall (CNHP, GLORIA principal investigator) to familiarize everyone with survey and safety protocols, and the purpose and need of using the GLORIA research methods. Because crew members were located across multiple locations, the full crew did not meet in person for training prior to field activities. Terutaka Funabashi was already familiar with the GLORIA protocol after sampling the Rocky Mountain National Park GLORIA site in 2019, the Great Sand Dunes National Park and Preserve GLORIA site in 2020, and the Pecos Wilderness GLORIA site in 2021. Alexa Armstrong and Emma Jordan met with Sarah Marshall in the alpine of Rocky Mountain National Park for a half-day of training prior to field activities. All field team members were provided the GLORIA methods handbook (Pauli et al. 2015), trip plans, itineraries, maps, and gear lists via email in advance of field activities.

Safety of the crew was the primary goal during the sample event, and as such, the crew reviewed situational awareness in the backcountry as well as used the satellite messenger device, SpotX, for safety check-ins. Given the frequency of lightning storms in the Rocky 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. Additionally, the crew reviewed grizzly bear safety protocols, including food storage precautions, grizzly bear behavior and appropriate responses, and proper use of bear spray (Montana Bear Education Working Group 2020; International Bear Association 2021).

## **Camp and Site Access**

The Betty Ford Alpine Gardens members of the crew traveled from Vail, Colorado, to meet with the CNHP members in Fort Collins, Colorado. Together, the crew traveled to 7D Ranch northwest of Cody, Wyoming, in two Jeep Wranglers. There, the crew handed off most of the field gear to the horse packers before heading to Little Sunlight Camping Area to camp for the evening. Little Sunlight camping area is a free, first-come, first-served dispersed campground in Shoshone National Forest. Bear boxes were available; however, there was no potable water. The following morning, the crew returned to 7D Ranch to hand off remaining gear before driving to Little Sunlight Trailhead.

The drive from Little Sunlight camping area to the Little Sunlight Trailhead along Forest Service Road 101/Sunlight Road was difficult and required crossing multiple technical stream crossings (Appendix B). Most of the 12-mile drive from Little Sunlight camping area to Little Sunlight Trailhead is along a well-graded gravel road; however, the high-water stream crossings and roads that were washed away during the historic flooding event in June 2022 caused the drive to be more difficult than usual. The stream crossing near Lee City (9.4 miles from Little Sunlight camping area) (44.66216, -109.72951 WGS84) was the most challenging. The water level reached the top of the

tires of the Jeep Wranglers, and the stream current was fast. After wading across the stream first to assess the stream bed, both Jeep Wranglers made it across with no issue. Other notable stream crossings occurred at 11 miles (44.66796, -109.75924 WGS84) and 11.8 miles (44.66888, -109.77387 WGS84) from Little Sunlight camping area. At 12.0 miles from Little Sunlight camping area, both vehicles were parked in a pullout and the crew began the hike to base camp. There is no trailhead sign marking the area; however, the crew hiked along the Sunlight Creek trail for 5.1 miles (2,221 feet elevation gain) to the backcountry campsite. The trail was littered with debris from the June flood and was washed out in multiple spots, yet the crew was able to reroute around these areas. The crew left the trail at a stream crossing around mile 3.9 (44.68773, -109.82949 WGS84) and followed a cross-country route to the campsite. The crew met with the horse packers at the backcountry campsite where they dropped off gear and left the crew with four sets of bear-proof metal panniers for food storage.

The crew utilized the same backcountry campsite (44.69495, -109.82832 WGS84) referenced in the 2016 trip report. The campsite is at 9,900 feet elevation, and the only flat area for tents is quite exposed (Figure 2). Access to water was on a steep slope of loose scree approximately 200 meters away. The crew stored all food, trash, and scented items in bear-proof panniers at all times. Wildlife sightings included deer, elk, ground squirrels, and moose (near Sunlight Creek on the drive in). While no bear sightings occurred, bear scat and tracks were observed.



**Figure 2.** Location of 2016 and 2022 backcountry campsite looking south.  
*NPS / TERUTAKA FUNABASHI*

Each morning of the expedition, the crew hiked along the ridge between Boundary Line Peak (BLP) and Stone Crop Peak (SCP), north and west of base camp. Hiking to the summits averaged 30 minutes to 1 hour; however, the hike is technical due to a steep slope and loose scree when cutting under the snowfield just before accessing the ridgeline. The technical hike (Class 2–3) posed a safety hazard and was uncomfortable for some members of the team. The crew tried an alternate hike one morning by hiking south of the base camp about 0.5 miles down to the creek crossing and joining the trail. From base camp, this ~1.75-mile hike to reach BLP was much less technical; however, the route loses much elevation only to regain it after the creek crossing.

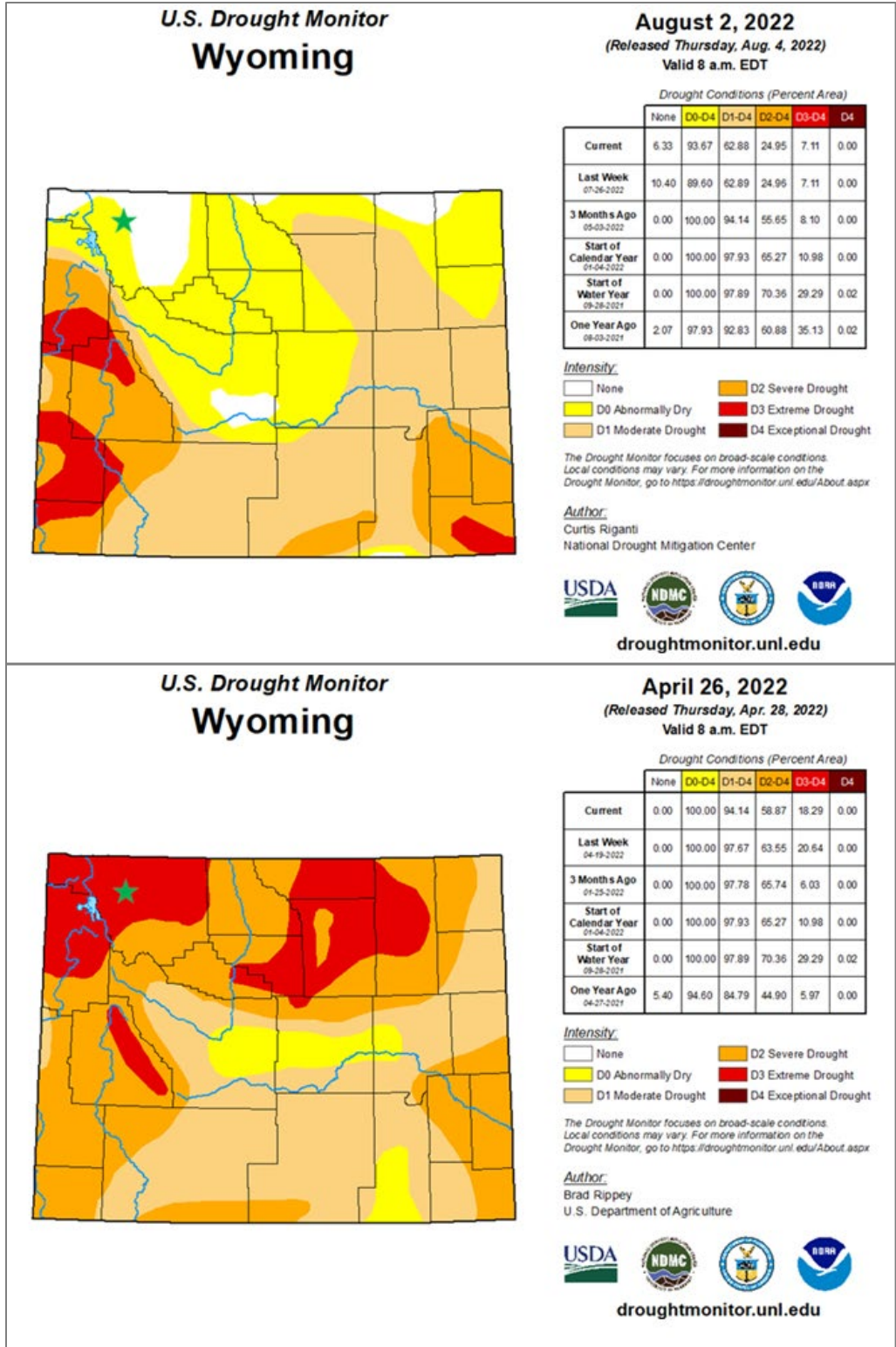
In future sample events, a lower elevation base camp is highly recommended. The horse packers recommended a location near the stream crossing around mile 3.9 (44.68773, -109.82949 WGS84) on the hike in. This campsite is around 2,804 meters elevation and has plenty of tree cover in the event of a lightning storm. It also has easy access to water from Sunlight Creek. From the lower base camp, hiking is on-trail to the summit of BLP. Access to all other summits is off-trail, yet gentle slopes and easy walking (Class 1). The crew was unable to move to the lower base camp in 2022, as they had no means to move the bear-proof metal panniers without the horse packers.

## **Research Site**

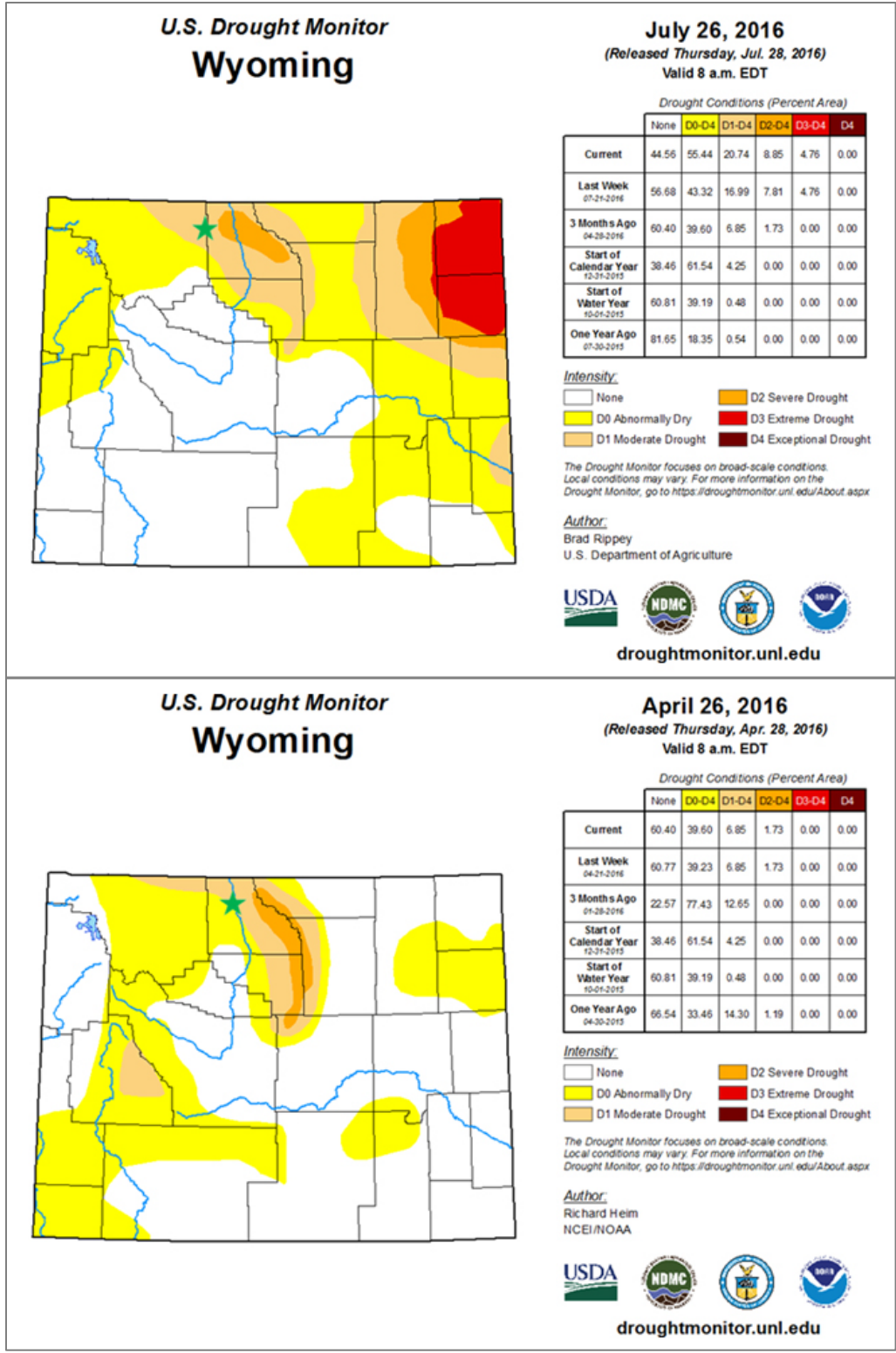
GLORIA sites are established on the tops of peaks (summits), and the summits vary from just above tree line to the highest life zones of vegetation. Within one region, all four summits share qualitatively similar geology, climate, disturbance, and land-use history, leaving vegetation differences among the summits to be driven primarily by elevation. The four summits sampled within Yellowstone National Park, Wyoming, are in close proximity to one another (all within ~1 mile), nearly all occurring on the ridgeline boundary between Yellowstone National Park and Shoshone National Forest (see Figure 1).

## Field Sampling

The 2022 alpine growing season in Yellowstone National Park was likely impacted by the surrounding region being abnormally dry to no-drought at the time of sampling and extreme drought the previous winter (Figure 3), compared to abnormally dry conditions in the summer and winter of 2016 (Figure 4) (National Drought Mitigation Center, 2022). Yellowstone National Park experienced a 500-year flood event in June 2022. Although the region was experiencing extreme drought in April 2022, the large amount of rainfall combined with late spring snowmelt created historic flooding in the area. This event reduced drought conditions to nearly absent in the sample area during the time of the visit in August 2022. This intense weather did not appear to hinder detection of key species. 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.



**Figure 3.** U.S. Drought Monitor Map for Wyoming at the time of GLORIA Yellowstone National Park sampling the summer of 2022 and in April 2022 (late April is considered the standard time for assessing peak annual snowpack in the region [NRCS 2023]). Star shows the location of the GLORIA site. NPS



**Figure 4.** U.S. Drought Monitor Map for Wyoming at the time of GLORIA Yellowstone National Park sampling the summer of 2016 and in April 2016 (late April is considered the standard time for assessing peak annual snowpack in the region [NRCS 2023]). Star shows the location of the GLORIA site.  
NPS

During data entry and QC, there were several discrepancies in species nomenclature between the YNP local species pool in the GLORIA database and the species list in the 2016 trip report (Table 2). While the GLORIA database identifies down to subspecies/variety, 2016 trip report uses species level identification. For most of these cases, it is confirmed that the subspecies or variety entered in the GLORIA database is the only subordinate taxon to occur in Wyoming. Consultation with Heidi Anderson, Yellowstone National Park botanist, further validated a few subordinate taxa. There are two varieties of *Potentilla diversifolia* (var. *glaucophylla* and var. *perdissecta*) possibly occurring in Yellowstone alpine areas; hence the species level identification was used. The list of species with nomenclature discrepancies was shared with the GLORIA coordination team to avoid any complications in data analysis.

**Table 2.** Discrepancies in species nomenclature between the GLORIA database and 2016 trip report (Authorities are not included)

In YNP local species pool in GLORIA database	In 2016 Trip report
<i>Achillea millefolium</i> var. <i>occidentalis</i>	<i>Achillea millefolium</i>
<i>Agoseris glauca</i> var. <i>dasycephala</i>	<i>Agoseris glauca</i>
<i>Androsace septentrionalis</i> ssp. <i>subulifera</i>	<i>Androsace septentrionalis</i>
<i>Astragalus kentrophyta</i> var. <i>tegetarius</i>	<i>Astragalus kentrophyta</i>
<i>Festuca brachyphylla</i> ssp. <i>coloradensis</i>	<i>Festuca brachyphylla</i>
<i>Oreostemma alpigenum</i> var. <i>haydenii</i>	<i>Oreostemma alpigenum</i>
<i>Poa glauca</i> ssp. <i>rupicola</i>	<i>Poa glauca</i>
<i>Potentilla diversifolia</i> var. <i>diversifolia</i> <sup>A</sup>	<i>Potentilla diversifolia</i>
<i>Smelowskia calycina</i> var. <i>americana</i>	<i>Smelowskia calycina</i>
<i>Solidago multiradiata</i> var. <i>scopulorum</i>	<i>Solidago multiradiata</i>

<sup>A</sup> Unable to confirm the subordinate taxon

Consultation with Heidi Anderson also revealed that specimens collected in 2016 sampling as *Festuca brachyphylla* turned out to be *Festuca idahoensis*. Considering that *F. idahoensis* was not common in the 2022 survey, it could be possible that *F. idahoensis* was misidentified as *F. brachyphylla* in some plots.

The crew sampled all four summits comprising the YNP GLORIA site over the course of five days. A summary of site access and setup is provided by summit, along with notes on observations and potential sampling errors. The general timeline of sampling activities is provided below.

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 begins taking overview photos, and photographing temperature logger locations, and moves 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 begins with the vegetation quadrats and is joined by the first team when their tasks are 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 2022. Snow Pipit Peak was sampled first, as it is the furthest point from base camp and weather was forecast to be clear that day. Stone Crop Peak was sampled next, followed by Wolf Scat Peak. Boundary Line Peak was sampled last. Total sampling time spent at each site gradually decreased as all crew members became more familiar with plants and the sampling protocol.

### **Snow Pipit Peak**

The crew took a total of 1.25 days (14.25 hours) to sample Snow Pipit Peak (SPP). The first day included calibration to ensure that new crew members were familiar with the GLORIA protocol and common plant species in the area.

#### ***Site Access and Set-up***

SPP is located approximately 0.75 miles overland hiking from the backcountry base camp (see Figure 1). It took approximately one hour for the entire crew to summit SPP carrying field gear. The crew started sampling at 07:00 and began the hike back to base camp at 18:45. The crew maximized time at the summit because weather remained clear all day, and they completed sampling in all areas except the North Summit Area (NSA). The crew returned the following day and completed the NSA from 07:45 to 10:20. An alternate route was used to access SPP on the second day with the objective to find a less technical route. The alternate route was accessed by hiking south of the base camp about 0.5 miles down to the creek crossing and joining the trail just east of the creek (Figure 5). From base camp, the 2.3-mile hike to reach SPP was much less technical; however, the route loses much elevation only to regain it after the creek crossing. The alternate route took approximately 1.5 hours.



**Figure 5.** Hiking on alternate route along trail to BLP and then SPP in Yellowstone National Park.  
*NPS / ALEXA ARMSTRONG*

Blowing rain and wind began around 09:00. The crew received word from their satellite messenger that the storm was going to be a long-duration system, so the crew retreated to base camp at 10:20. That afternoon, the crew quality-checked datasheets and identified unknown plant specimens collected at the summit.

The crew used SPP as a calibration peak, including site setup, to ensure consistency in plant ID and plot sampling across researchers. Nails were missing from N31, N33, W33, p10m-N, and p10m-W, but the crew was still able to set up each plot and grid based on the photo documentation from the 2016 sampling. Replacement for the missing nails was not installed at this time.

The crew noticed that the intermediate point for pSE-10 was not on the direct line between p10m-S and p10m-W; rather, it lies on the contour line. The site was set up with the original measurements to make it consistent with past sampling. The difference in the species list for the summit area sections (SASs) was not examined at this site (see the Boundary Line Peak section for a similar issue).

### **Observations and Sampling Errors**

The crew observed a patch of snowpack right outside of the summit area boundary on the east side. No apparent disturbance was observed within and near the site, but a herd of elk was spotted about 500m below on the south side.

During the 1-m<sup>2</sup> quadrats recording, several crew members identified *Selaginella densa* as bryophytes and this error was corrected in the field. There were two plots where the sum of plant species cover was smaller than the top cover of vascular plants. The recorded end time was missing on a few data sheets, which was later estimated based on the recorded start time of other plots.

### **Stone Crop Peak**

The crew took a total of 1.25 days (11 hours total) to sample Stone Crop Peak (SCP). Sampling was split over three days due to challenging weather. On the second day of sampling, the crew had retreated to base camp in the morning after finishing sampling SCP due to an incoming storm. The storm cleared in the evening of the second day, so three crew members left base camp at 17:30 to set up the plot at SCP. They returned to base camp at 20:00. On the third day of sampling, the weather window was very short so the crew sampled the south SAS and all S 1-m<sup>2</sup> quadrats from 09:40-12:00. The crew sampled through dense fog, cold temperatures, and drizzle and decided to begin the hike back to base camp at 12:15. Heavy rain started at 12:30. Back at camp, the crew quality checked datasheets and identified unknown plant specimens collected at the summit. On the fourth day of sampling, the crew finished the remaining SAS and 1-m<sup>2</sup> quadrats on SCP from 06:00-13:30 (Figure 6). With clear skies that afternoon, the crew started the hike to WSP to begin sampling.



**Figure 6.** Sampling quadrats on Stone Crop Peak in Yellowstone National Park.  
NPS / ALEXA ARMSTRONG

### **Site Access and Set-up**

SCP is located approximately 0.5 miles of overland hiking north and west from the backcountry base camp (see Figure 1). It took approximately 45 minutes to an hour for the entire crew to summit SCP using this route.

All nails were found, but the crew had a hard time locating some of them. Crew members used photos to estimate where the nails were located and dug through the dirt in those areas to locate them. The intermediate point (pSW-10) was not on the direct line between p10m-S and p10m-W, but rather on the contour line, which leads to larger SASs. Original measurement was used to establish the site for consistency. We noted the new measurement for pSW-10 that was more appropriate in the comments section of Form 1 (Measurement Protocol). The crew did not assess the effect of the new measurement on the SAS species lists.

### **Observations and Sampling Errors**

Stunted trees (*Picea engelmannii* and *Pinus albicaulis*) were scattered across the north side of SCP. PG11 and PG12 were common on this site and later identified as *Agrostis scabra* and *Agrostis*

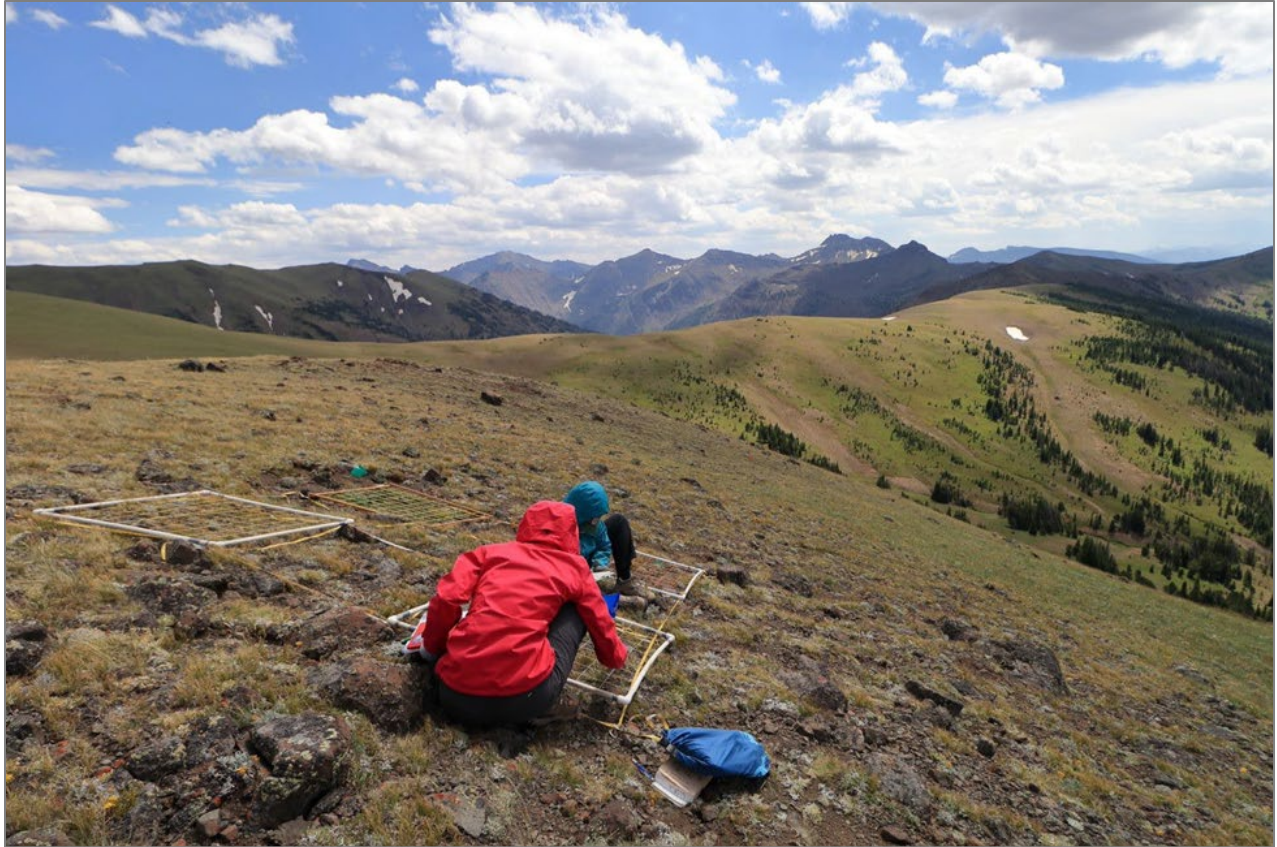
*variabilis* by Alexa Armstrong. These species are newly added to the YNP species list. Genus *Anemone* was also newly recorded in SASs (S05, S10), but the crew was not able to identify it down to species due to the lack of a flowering part. The crew observed signs of native herbivory and rodent activity including munched grasses, old scat, and rodent burrows, although the area of disturbance was minimal. *Eritrichium nanum* and *Dryas octopetala* were observed on SCP (Figure 7).



**Figure 7.** *Eritrichium nanum* (left) and *Dryas octopetala* (right) on SCP in Yellowstone National Park.  
NPS / ALEXA ARMSTRONG

### **Wolf Scat Peak**

The crew took a total of 1.25 days (10 hours total) to sample Wolf Scat Peak (WSP). Sampling was split over two days due to finishing the sampling of SCP on the morning of the fourth day of sampling and beginning WSP that afternoon around 13:00 (Figure 8). With clear weather, the crew sampled until 19:45 and then returned to base camp. On the fifth day of sampling, the crew completed sampling WSP from 06:45–10:00. The crew then began the hike to BLP, the final summit.



**Figure 8.** Sampling quadrats on WSP in Yellowstone National Park.  
NPS / TERUTAKA FUNABASHI

### **Site Access and Set-up**

WSP is located approximately 0.75 miles of overland hiking north and west from the backcountry base camp (see Figure 1). SCP is passed along the way. It took approximately 45 minutes for the crew to summit WSP from the backcountry base camp. Like other summits, soil and litter buildup made it difficult for the crew to find the nails. We could not locate the nails for 1-m x 1-m quadrats (p-E33, p-E13, and p5m-W31) and used photos from the previous sampling to set up the clusters. More detailed, close-up photos of these points were taken for future sampling.

### **Observations and Sampling Errors**

The summit is relatively flat around its high summit point (HSP). The HSP and the west side of the summit are characterized by thick vegetation with mixed graminoids (*Carex elynoides*, *Poa glauca*) and forbs (mainly *Lupinus depressus* and *Polemonium viscosum*). Like SPP, a patch of snow was observed below the east boundary of the summit area.

Anthropogenic disturbance was minimal, which is likely a result of the summit being farther away from the main trail. No wildlife species were observed. Initially, *Phlox pulvinata* was misidentified as *Phlox multiflora*. All *P. multiflora* records were changed to *P. pulvinata* in WSP 1-m<sup>2</sup> quadrats and summit area sections. If both species were observed in a single summit area section, *P. multiflora* was kept in the final database. We noted all the modifications in the original data sheets.

## **Boundary Line Peak**

The crew took one day (9.25 hours total) to sample Boundary Line Peak (BLP). On the fifth day of sampling, the crew completed sampling WSP and then headed to BLP, sampling from 09:45–19:00. Clear skies all day allowed the crew to wrap up sampling on the fifth day before heading back to base camp.

### **Site Access and Set-up**

BLP is located approximately 0.5 miles of overland hiking north, west, and northeast from the backcountry base camp (see Figure 1). Once the ridge between BLP and SCP was accessed, the crew headed northeast to the summit.

Several crew members tried to set up the plot in the late afternoon of August 5, but they could not locate the HSP nail without the photos and decided to set up SCP instead. Later, the crew contacted Sarah Marshall and Joanna Lemly at CNHP via email to obtain the required photos. The crew surveyed BLP on August 8. The nail on HSP was completely covered by thick vegetation. Soil and litter buildup also covered some of the p10m markers, which made them difficult to locate, especially where the slope was steep.

### **Observations and Sampling Errors**

The northern half of the site is diverse and characterized by a gradual slope with relatively dense vegetation. A large patch of *Salix petrophyta* was noticeable with inflorescence in the northwestern section. In contrast, the south side of the site consists of a steep slope with less vegetation and diversity (Figure 9). There is a trail going through the northeast section of BLP, and the rock pile marking the trail is within the N10m summit area section. We did not observe obvious signs of severe anthropogenic disturbance off the trail, though we collected small pieces of trash near the boundary of the site. When setting up the southwest intermediate line based on the 2016 measurements and photos, we noticed that the intermediate point (pSE-10) was not on the direct line drawn between the principal measurement points (p10m-S, p10m-E). The new measurement was taken for pSW-10, and this resulted in missing two species in the summit area section of East, 10 m compared to the original set-up. In the GLORIA database, the data for E-10m summit area section was entered based on the original measurement. There was no effect on the species list for the summit area section of South, 10 m.



**Figure 9.** Plot set-up on Boundary Line Peak in Yellowstone National Park.  
*NPS / ALEXA ARMSTRONG*

# Notes for Future Sampling

## General Tasks Prior to next GLORIA Sampling Event (2027)

1. Rebuild and/or replace 1 m x 1 m 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 hiking pole.
3. 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 reduce the risk of biasing plant lists and identification.
4. In addition to quadrat photos, print out and bring photos of the HSP and Entire Summit for BLP as it is difficult to locate the markers due to dense vegetation and soil buildup.

## Logistical Notes for Future Sampling Events

1. Because of scheduling conflicts and the fact that crew members were located in multiple locations, the full crew did not meet in person for training prior to field activities. Before future sampling events, it would be helpful for as many crew members as possible to meet for a full day of training. Part of the day could be spent reviewing the GLORIA protocol, equipment, data collection procedures, and reports and important notes from the previous sampling event. Additionally, it would be beneficial for the crew to spend a half-day in the alpine (e.g., off Trail Ridge Road in Rocky Mountain National Park) with a botanist to review common alpine plant species and practice calibrating cover estimates. While the plant community at YNP is different, many of the more common alpine species occur in alpine areas of both parks. For team members who could not attend in-person training in advance of the GLORIA visit, training could occur at base camp the night before sampling.
2. At present, it is not possible to reserve campsites at Little Sunlight Camping Area, the campsite the crew used the night before hiking into the backcountry. It is advisable that future crews arrive on a weekday. In 2022, the crew arrived on a Tuesday night, and only a couple campsites were available. It is also important to bring plenty of water, as there is no potable water at this campsite.
3. In future sample events, it is recommended to utilize the lower elevation backcountry base camp rather than the higher elevation base camp (44.69495, -109.82832 WGS84), which the crew used in 2022. The higher elevation base camp (3,017 meters) is very exposed to lightning storms, has limited flat ground for tents (seven backpacking tents fit only by being close together), and accessing water is difficult (downclimb a steep drainage ~200 m northwest of base camp). Most notably, the hike to access summits (although a shorter distance) is technical and includes off-trail scrambling on steep and loose scree (Class 2–3) to access the ridgeline northwest of the base camp. The hike was uncomfortable for some

members of the team and could pose a safety hazard due to risk of falling or injury. Camping at the lower elevation base camp (9,200 feet) would involve slightly longer hikes to reach the summits; however, the hike is all on trail until the BLP summit is reached (~1.75 miles). Access to all other summits is off-trail with gentle slopes and easy walking (Class 1). The lower elevation base camp is located near the stream crossing (see Figure 1) around mile 3.9 (44.68773, -109.82949 WGS84) on the hike in. The lower elevation base camp has plenty of tree cover in the event of a lightning storm and has easy access to water from Sunlight Creek. The benefits of camping at the lower elevation base camp far outweigh the disadvantages and the slightly longer hike would not add a significant amount of time.

4. The crew may have benefited from having an additional crew member, especially a botanist familiar with the flora of Yellowstone National Park. It is important to have a minimum of two botanists present; however, more would be better. In 2022, the crew was comprised of seven people, which was fairly efficient. It would not be recommended to have less than seven people. The workflow at each summit was as follows: two people set up the plot, took photos, completed Form 1 (Measurement Protocol) and Form 2 (Land Use, Human Disturbance, and Natural Disturbances), and helped with 1-m<sup>2</sup> quadrats as time allowed; two people collected data in 1-m<sup>2</sup> quadrats; and three people completed data in SAS (with one sometimes splitting off to help identify plants or complete a SAS solo).
5. Sampling time at each summit gradually decreased throughout the trip—SPP: 14.3 hours, SCP: 11 hours, WSP: 10 hours, and BLP: 9.3 hours. Keep this in mind in future sampling events as the crew will likely become more efficient as they become more familiar with the protocol and flora.
6. Ensure that the crew is clear on visual estimation of top cover versus total cover and calibration should be completed up front. While the crew covered this at the beginning of sampling, 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.
7. Ensure that the crew is clear on the meaning of “litter” in the GLORIA protocol, as some crew members had different ideas about litter based on working on different protocols. In this protocol, litter is all dead plant material, whether attached or unattached to the plant.
8. Stress the importance of clear, legible writing on field forms and consider whether digital data collection where possible or more efficient. The 2022 crew did not attempt digital data collection, partly due to being in the backcountry for the entire sampling period. It may be worth testing digital data collection options prior to the next sampling event. If electronic data collection is used in the future, data forms and references should be available on multiple devices, with portable battery chargers at all times. A solar charger would also be crucial.
9. In 2022, crews utilized the following botanical resources for plant identification: Vascular Plants of Wyoming 3<sup>rd</sup> ed. by Dorn, Alpine Flower Finder 2<sup>nd</sup> ed. by Wingate and Yeatts, Alpine Wildflowers of the Rocky Mountains by Duft, Field Guide to Sedge Species of the Rocky Mountain Region by Johnston, A Field Guide to Wyoming Grasses by Skinner, Flora

of Colorado 1<sup>st</sup> ed. by Ackerfield, Colorado Grasses with Illustrated Keys by Wingate, and Sedges of Colorado by Wingate, and Alpine Plants of the Northwest by Pojar.

10. The crew had no cell phone reception for almost the entire duration of the sampling period, including the base camp site and on most summits (there was some spotty reception on the northwest portions of SCP and WSP with Verizon). The crew had two 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, so communication remained available between the two parties.
11. It is important to check the status of both Forest Service Road 101/Sunlight Road and Sunlight Creek Trail in the weeks before the next sample event. Forest Service Road 101 has many creek crossings and was difficult to drive following the flooding events in June 2022 as parts of the road had been washed away. The most difficult stream crossing was near Lee City (9.4 miles from Little Sunlight Camping Area) (44.66216, -109.72951 WGS84). Sunlight Creek Trail had many down limbs, in part due to the flood, but also because the road to access the trail is closed throughout the winter and opens in mid-July, so the trail gets little to no human use throughout parts of the year. In 2022, the road opened on July 16. It is recommended to check with National Park Service and Forest Service contacts to see if anyone is available to scout the area. The horse packers at 7D Ranch may also be able to provide a status update on the condition of the road and trail. In 2022, Forest Service crews planned to conduct whitebark pine surveys on July 21; however, they were not able to make it to the trail as they turned around at the Lee City creek crossing due to high water levels. 7D Ranch was able to drive the entire length of the road to the trailhead on July 23, 2022, in a pickup truck and reported back that the trail would require clearing as there were so many down trees. 7D Ranch charged \$200 for the trail clearing.
12. As this GLORIA site is in grizzly country, it is important to take extra safety precautions. Each crew member should have their own bear spray mounted and accessible at all times (i.e., on the chest strap or belt loop). Crew should also practice using the spray with an inert bear canister prior to the trip so that each person is prepared in the event of a bear encounter. It is recommended to talk through different scenarios and how to respond. Watching the grizzly safety videos noted in the Training section of this report is very helpful.
13. Each crew member carried an N95 mask in the event wildfire smoke was present. No wildfire smoke was present during this sampling event, but it is advisable to bring N95 masks on future trips in case of poor air quality.
14. It is highly recommended that additional measures be taken to protect water filters from clogging (e.g., wrapping the prefilter in a handkerchief or other cloth). Multiple water filters should be carried on future expeditions.
15. Bring at least 11 nails to replace plot markers that were missing, including:
  - p10m-S, p10m-W, p5m-E31 on BLP
  - p5m-E13, p5m-E33, p5m-W31 on WSP

- p10m-N, p10m-W, p5m-N31, p5m-N33, p5m-W33 on SPP

## Conclusion

The 2022 YNP survey crew was able to successfully sample all four GLORIA summits at a rate of 1.3 days per summit, spread across five days. The total trip was eight days including travel from Fort Collins, Colorado, and hiking to the backcountry base camp. Efficiencies were gained by dividing the crew into 3–4 smaller teams on several occasions, allowing the first team to set up the summit grid and take photographs, the second team to assess plots and the third team (and sometimes fourth team of one person) to complete summit area section assessments.

When analyzing the data for 2022, it will be important to consider that there were several occasions where the sums of vascular plant species cover were smaller than top cover estimates for vascular plants. To correct this error, the top cover of each surface type was reassessed and adjusted by reviewing the quadrat photos and point-intercept values. Adjustments were also made to plant species cover for the species that are obvious in the quadrat photos (e.g., *Lupinus depressus*) when it is appropriate. All modifications were noted in both original datasheets and the GLORIA database. It is also worth noting that some records of *Festuca brachyphylla* might possibly be *Festuca idahoensis* if there is significant change in the presence or absence of these species.

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## Appendix A: US-YNP 2022 Field Log

**Table 3.** The daily field log for Yellowstone National Park, August 2–9, 2022, including crew members, activities, and notes. “–” = no peak

Date	Peak	Persons	Activities	Notes
8/2/2022	–	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul (Betty Ford Alpine Gardens), and Olivia Sena (Betty Ford Alpine Gardens)	Travel from Fort Collins, CO to 7D Ranch and then, Little Sunlight Camping Area for car camping overnight.	8.25 hr drive from Fort Collins. The majority of gear (besides camping gear needed for one night) was handed over to 7D Ranch for them to begin packing.
8/3/2022	–	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	Hiked in to higher elevation backcountry base camp. Set up camp, reviewed protocol and calibrated cover estimates.	Met horse packers at 7D Ranch at 07:00 to hand off remaining gear. Drove FS Road 101 to trailhead and hiked ~5.1 miles on Sunlight Creek Trail (and partially off-trail) to reach backcountry camp site. Met horse packers at site, unloaded gear, and set up camp.
8/4/2022	Spring Pipit Peak (SPP)	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	Site set-up, sampled all but N SA.	Departed camp at 05:30, group arrived at SPP and began sampling at 07:00. Departed SPP at 18:45 and arrived at base camp around 19:30.

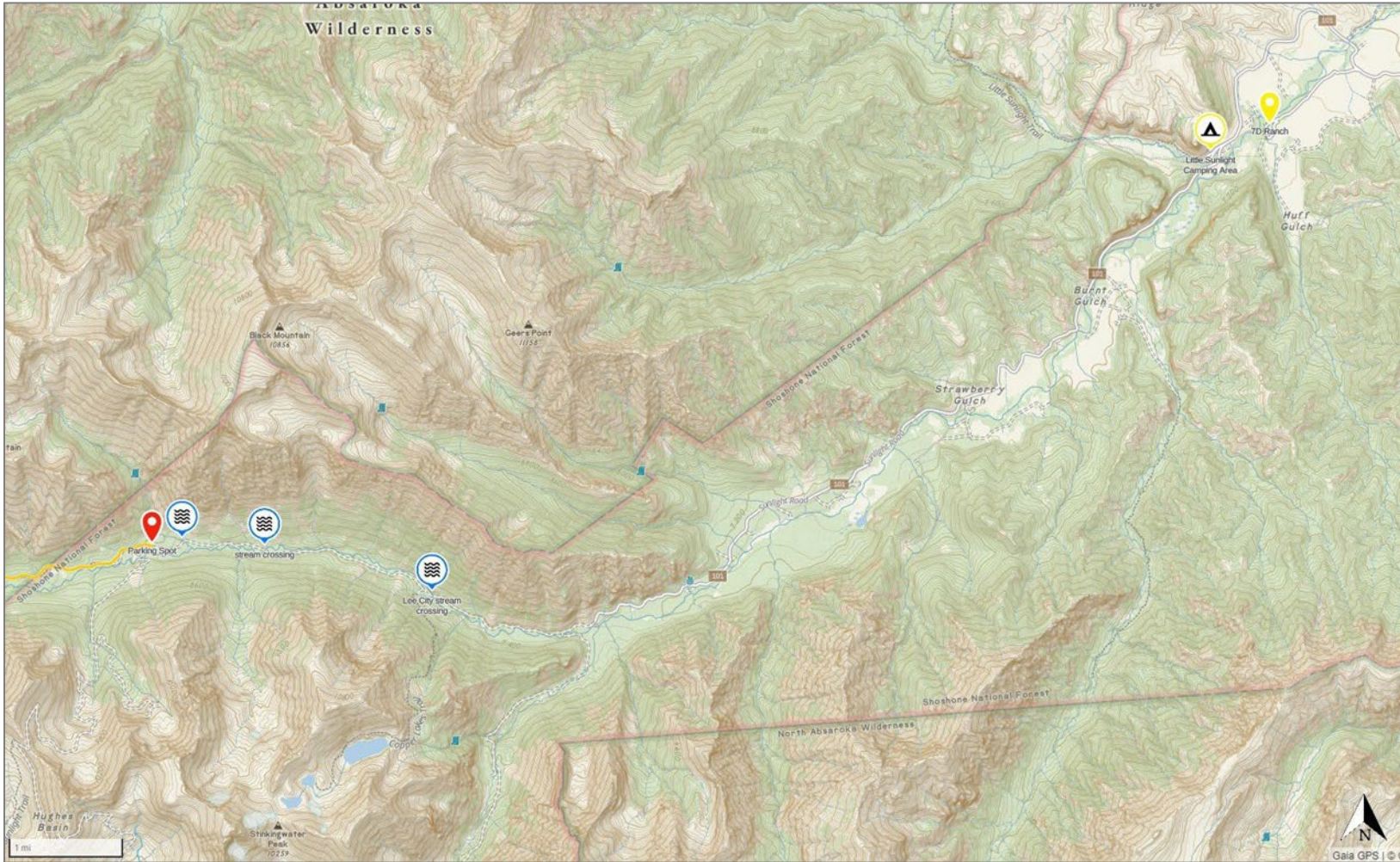
**Table 3 (continued).** This appendix table provides the daily field log for Yellowstone National Park, August 2–9, 2022, including crew members, activities, and notes. “–” = no peak

Date	Peak	Persons	Activities	Notes
8/5/2022	SPP & Stone Crop Peak (SCP)	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	SPP: Finished N SA. SCP: site set-up. QC and plant ID at camp.	Departed camp at 5:15 and hiked the alternate route by backtracking south to meet up with the trail. Crew sampled SPP from 7:45-10:20. Blowing rain and wind started at 09:00. The crew decided to hike back to base camp at 10:20 as the storm increased and arrived at base camp at 12:15. The afternoon was spent QCing data and identifying plants. It stopped raining around 17:00, so 3 crew members hiked to BLP. They could not locate markers, and thus they set up plots at SCP and returned to base camp at 20:00. It then rained heavily through the night.
8/6/2022	SCP	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	Sampled S SA and S 1m <sup>2</sup> cover plots. QC and plant ID at camp.	Departed camp at 08:30 as the rain lightened and sampled SCP from 09:40-12:10. Cold temperatures, fog, and rain led the crew to depart SCP at 12:15. Heavy rain started at 12:30. At camp, the crew QC'ed data and identified plants.

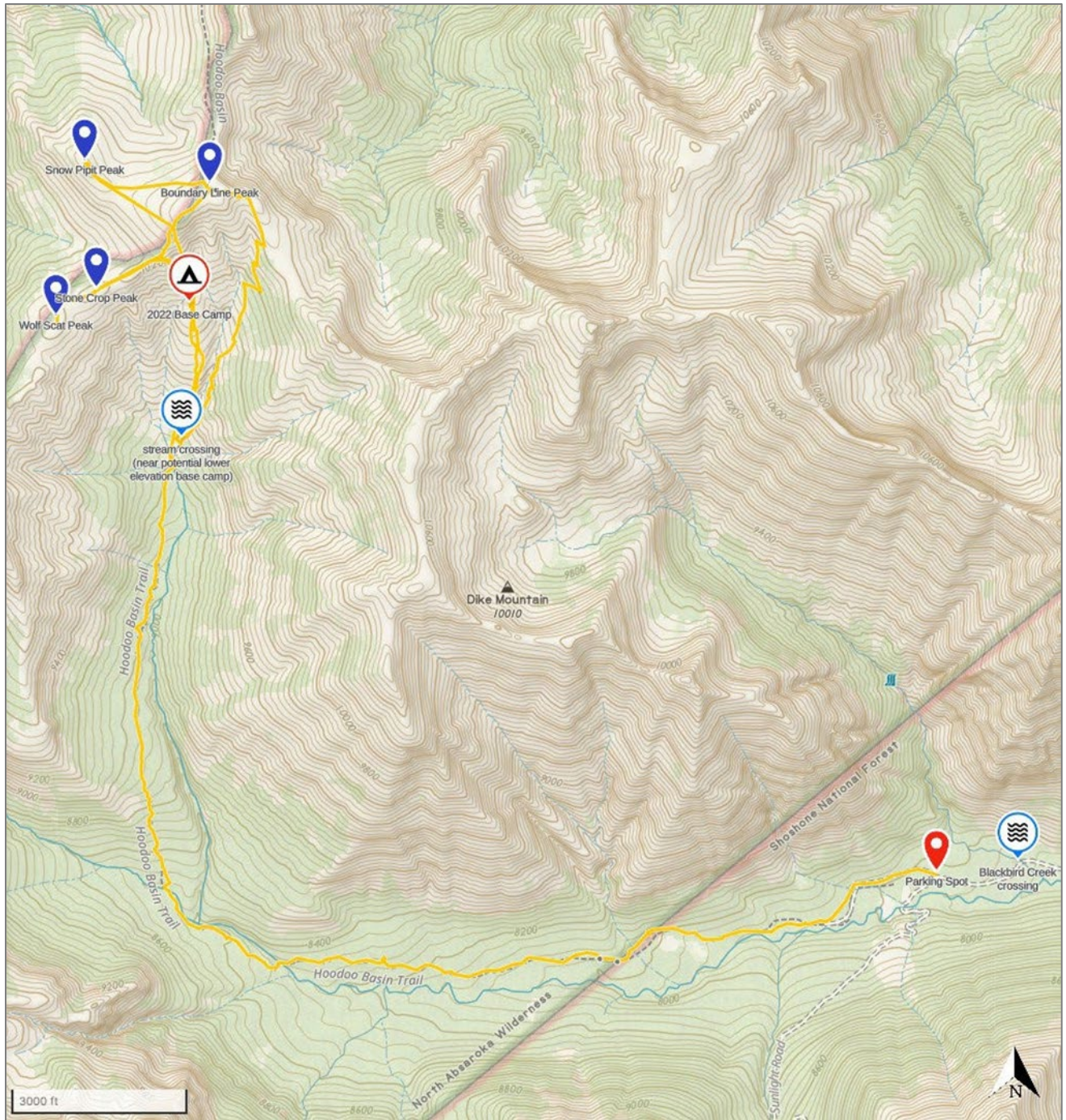
**Table 3 (continued).** This appendix table provides the daily field log for Yellowstone National Park, August 2–9, 2022, including crew members, activities, and notes. “–” = no peak

Date	Peak	Persons	Activities	Notes
8/7/2022	SCP & Wolf Scat Peak (WSP)	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	SCP: Finished sampling SAs (6) and 1m <sup>2</sup> cover plots (12). WSP: Site set-up, SAs (6), 1m <sup>2</sup> cover plots (12).	Departed camp at 05:15 and sampled SCP from 06:00-13:30. Two crew members left early to begin set-up at WSP. The entire crew met at WSP at 14:00. The crew sampled WSP from 13:00-19:45. The crew returned to base camp at 20:10.
8/8/2022	WSP & Boundary Line Peak	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	WSP: Finished sampling SAs (2) and 1m <sup>2</sup> cover plots (4). BLP: Site set-up, SAs (8), 1m <sup>2</sup> cover plots (16).	Departed camp at 05:45 and sampled WSP from 06:45-10:00. Two crew members left early to begin set up at BLP. The entire crew met at 10:30. The crew sampled BLP from 09:45-19:00. The crew returned to base camp at 20:00.
8/9/2022	–	Alexa Armstrong, Terutaka Funabashi, Emma Jordan, Brennan Kurosad, Abigail Rios, Emily Griffoul, and Olivia Sena	Pack up backcountry base camp and helped load gear with horse packers. Hiked out of backcountry. Travel home.	Horse packers arrived at base camp at 13:15. Crew helped load gear and began hike out at 13:45. Hike out took ~2 hours. Drove jeeps to pick up gear from horse packers at pre-determined parking spot. Then, drove back to Fort Collins, CO. Crew arrived at Fort Collins at 03:00 on 8/10.

## Appendix B: US-YNP 2022 Route Maps



**Figure 10.** Overview of driving route along FS101 from Little Sunlight Camping area to parking spot. The parking spot is located shortly after the Blackbird Creek crossing. Hiking route shown as solid yellow line.  
NPS



**Figure 11.** Overview of driving route along FS101 from Little Sunlight Camping area to parking spot. The parking spot is located shortly after the Blackbird Creek crossing. Hiking route shown as solid yellow line. NPS

## Appendix C: National Park Service Resource Staff and Leadership

The following National Park Service staff provided program leadership, technical expertise, and resource management support for this project. Their roles and contact information are listed for reference

Kristin Legg  
Program Manager-Ecologist  
Greater Yellowstone Network  
National Park Service  
Bozeman, MT  
406.994.7734  
[Kristin\\_Legg@nps.gov](mailto:Kristin_Legg@nps.gov)

Heidi Anderson  
Yellowstone Park Botanist/Wetland Ecologist  
Yellowstone Center for Resources  
Yellowstone National Park  
307.344.2564  
[Heidi\\_Anderson@nps.gov](mailto:Heidi_Anderson@nps.gov)

Ann Rodman  
Supervisory GIS Specialist  
Yellowstone Center for Resources  
Yellowstone National Park  
[Ann\\_Rodman@nps.gov](mailto:Ann_Rodman@nps.gov)

## Appendix D: 7D Ranch Contact Information

The 7D Ranch supported field operations by providing logistical services and pack support. Contact information for the ranch is included here for reference.

### **7D Ranch**

Website: [7dranch.com](http://7dranch.com)

Contact: Meade and Andrea Dominick Contact

Email: [ranch7d@wyoming.com](mailto:ranch7d@wyoming.com)

Office: 307.587.9885

Cell: 307.899.1490

**National Park Service  
U.S. Department of the Interior**



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**Natural Resource Stewardship and Science**

1201 Oakridge Drive, Suite 150  
Fort Collins, CO 80525