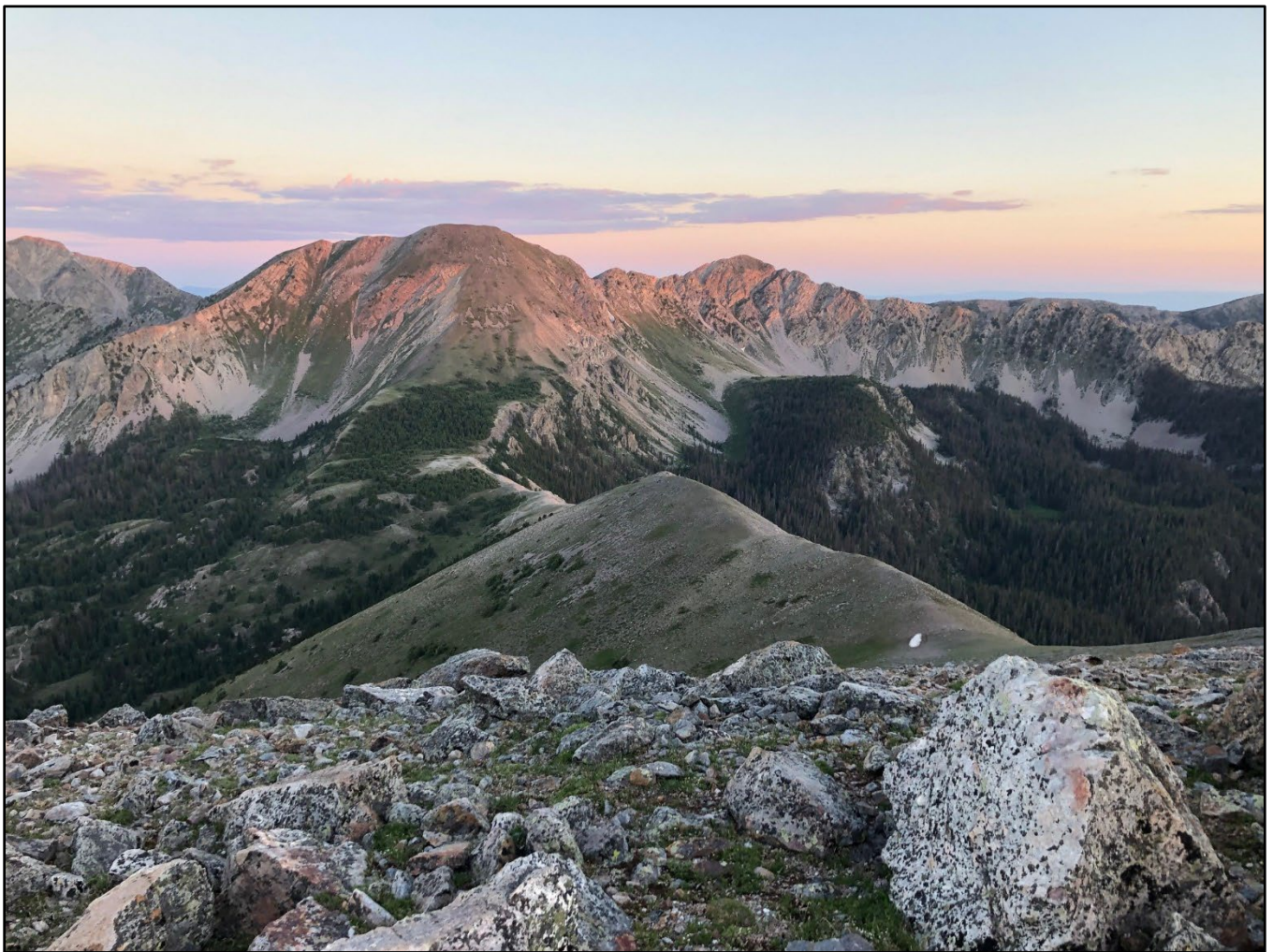




Alpine vegetation composition and structure monitoring for Pecos Wilderness, New Mexico

2021 Trip Report



ON THE COVER

A view from Chimayosos peak looking west toward the other three surveyed GLORIA summits in Pecos Wilderness, New Mexico. Photo: Andrea Schuhmann, July 2021.

Alpine vegetation composition and structure monitoring for Pecos Wilderness, New Mexico

2021 Trip Report

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National Park Service
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Fort Collins, Colorado

Contents

	Page
Summary and Background.....	4
Acknowledgments.....	5
Introduction.....	6
Training	6
Camp and Site Access	7
Research Site	8
Field Sampling.....	10
CHI	14
Site Access and Set-up	14
Observations and Sampling Errors.....	15
WCP	17
Site Access and Set-up	17
Observations and Sampling Errors.....	17
NFP.....	17
Site Access and Set-up	18
Observations and Sampling Errors.....	18
NTP	18
Site Access and Set-up	18
Observations and Sampling Errors.....	19
Notes for Future Sampling.....	19
General Tasks Prior to 2026 GLORIA Sampling Event	19
Logistical Notes for Future Sampling Events	20
Conclusion	21
References.....	22
Appendix A: US-PECO 2021 Field Log.....	23
Appendix B: Adjustment of 2021 field substrate data.....	24

Appendix C: US-PECO 2021 Route Map to Base Camp	26
Appendix D: U.S. Forest Service Contacts and Carson National Forest, Forest Supervisor Letter of Support	27
Appendix E: Area Outfitters Contacted for Pack Support.....	29
Appendix D: U.S. Forest Service Contacts and Carson National Forest, Forest Supervisor Letter of Support.....	27
Appendix E: Area Outfitters Contacted for Pack Support.....	29

Figures

	Page
Figure 1. Locations of the four peaks in Pecos Wilderness, New Mexico, and overview of 2021 access routes to reach each summit from Base Camp. Hiking routes shown as a solid yellow line.	9
Figure 2. U.S. Drought Monitor Map for New Mexico at the time of GLORIA Pecos Wilderness sampling the summer of 2021 (upper) and the previous winter (lower). Star shows the locations of the GLORIA site.	12
Figure 3. U.S. Drought Monitor Map for New Mexico at the time of GLORIA Pecos Wilderness sampling the summer of 2016 (upper) and the previous winter (lower). Star shows the locations of the GLORIA site.	13
Figure C-1. Overview of 2021 hiking route from Santa Barbara Campground to Backcountry Base Camp.	26

Tables

	Page
Table 1. Name, location, elevation, and vegetation zone of the four alpine sites within the PECO target region.	10
Table 2. Species discrepancies observed between 2016 and 2021 PECO sampling events.	11

Summary and Background

The purpose of the National Park Service (NPS) Inventory & Monitoring (I&M) Program is to develop and provide scientifically credible information on the current status and long-term trends of the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. The Rocky Mountain I&M Network (ROMN) identified alpine 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 Pecos Wilderness (PECO) Global Observation Research Initiative in Alpine Environments (GLORIA) alpine monitoring site was established in 2016 to study the impacts of climate change on alpine vegetation composition and soils over time. It is the southern-most GLORIA site in the Rockies. The timeline for activities at this site includes the following events:

- An alpine monitoring site was established at Pecos Wilderness, New Mexico (PECO) in 2016 following the GLORIA protocol.
- Four sentinel sites were established in 2016 on the summits of Chimayosos peak (CHI), North Truchas Peak (NTP) and two unnamed peaks – hereafter referred to as West Chimayosos Peak (WCP) and No Fish Peak (NFP) – in the surrounding area. The established sentinel sites included sixteen 1-m² 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.
- All four sentinel sites or summits were sampled again in 2021. The sampling event occurred over a single 7-day field hitch, including travel. All 1-m² quadrat clusters and summit area sections were resampled for each peak. Temperature loggers were retrieved and replaced by Bandelier National Monument staff in September 2021 because new temperature loggers were not available at the time of vegetation sampling.

GLORIA sites are typically surveyed in five-year intervals for vegetation composition, structure and soil temperature. In 2016, the four summits were observed “to be a system little impacted by human disturbance or exotic species,” with the exception of light recreation impacts on North Truchas Peak (Tortorelli et al. 2017). Recreational use on Chimayosos Peak and North Truchas Peak was observed in 2021, along with animal disturbance (e.g., Bighorn sheep and small mammal browsing and burrowing activity) across all four peaks.

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

Acknowledgments

We would like to thank all who assisted with preparation, training, field work, and data management and gave knowledge and insight necessary for the second iteration of this study. We want to acknowledge the hard work of the 2016 GLORIA team that established the PECO sites and initiated the inclusion of the Pecos Wilderness (southern-most GLORIA site in the Rockies) in the existing GLORIA network. Special thanks goes to the 2021 field crew: Terutaka Funabashi, Tai Mei Chang, and Chris McCormick with the Colorado Natural Heritage Program; Ella Kasten and Kara Fox with Bandelier National Monument; and Patrick Alexander with the Bureau of Land Management's Las Cruces field office – Patrick provided invaluable botanical expertise of the New Mexico flora. We thank Kay Beeley with Bandelier National Monument for help coordinating field logistics, safety check-ins, arranging critical pack support services from four Bandelier staff when horse packer options fell through, and coordinating temperature sensor retrieval and replacement. Special thanks also goes out to Sarah Marshall (CNHP), Megan Swan (NPS), and Erin Borgman (NPS) for their help with project planning, coordination, and data analysis. Lastly, we appreciate the efforts of Josh Hall, Michael Lujan, and Paul Schilke – all with the U.S. Forest Service – for their assistance securing permissions/permitting for our research.

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 Pecos Wilderness, New Mexico (PECO) monitoring site is the southernmost GLORIA alpine monitoring site in the Rocky Mountains of North America. Plot installation and the initial sampling of the four sentinel sites (summits) took place in 2016. In 2021, 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.

In 2021, a field crew from CNHP, Bandelier National Monument, and Bureau of Land Management completed resampling of all four summits (Figure 1) within the Pecos Wilderness over the course of seven days. The following summary outlines key information about how the site was sampled and lessons learned that may be applied to future sampling events.

Training

Prior to conducting field surveys at the PECO site, the field crew (Terutaka Funabashi, Tai Mei Chang, Chris McCormick, Kara Fox, Ella Kasten, and Patrick Alexander) coordinated remotely with Andrea Schuhmann (CNHP, PECO 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 in two different states, 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 Rocky Mountain National Park GLORIA site in 2019 and Great Sand Dunes National Park and Preserve GLORIA site in 2020. Andrea Schuhmann 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 2016 trip reports, the GLORIA methods handbook (Pauli et al. 2015), trip plans/itineraries and gear lists via email in advance of field activities.

Given the frequency of lightning storms in the Sangre de Cristo Mountains and the active North American Monsoon system in 2021, 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.

Camp and Site Access

The CNHP members of the crew traveled from Fort Collins, Colorado and the Bandelier National Monument (NPS) members (including 4 staff providing pack support on hike into backcountry) traveled from Los Alamos, New Mexico to meet at the U.S. Forest Service Santa Barbara Campground in the Carson National Forest for a one night stay (*note: two campsites were reserved in advance through recreation.gov, but a single double-occupancy campsite was large enough to accommodate the group of 10*). Patrick Alexander traveled from Las Cruces, New Mexico to rendezvous with the crew and confirm the location of the crew's backcountry campsite before backpacking along the West Fork Santa Barbara Trail 25 to collect plant specimens for another unrelated project. The 2016 crew was able to secure and utilize USFS pack animal support for the trip into and out of the backcountry. Pack support was not available through USFS in 2021. Several private outfitters known to work in the area were contacted (Appendix D), but assistance could not be secured, therefore, 4 Bandelier National Monument staff helped carry equipment and gear to the backcountry campsite.

Access to the West Fork Santa Barbara Trail 25 trailhead can be found at the north or south end of the Santa Barbara Campground loop. Overnight trip parking can be found on the north side of the Santa Barbara Campground gate. The campground host was notified of our planned activities and timeline. Travel along the West Fork Santa Barbara Trail 25 to the backcountry campsite is approximately 7 miles.

A large backcountry campsite (13S 0444022E 3982162N, WGS84), referenced in the 2016 trip report as "No Fish Lake", was utilized as a base camp for the duration of all 2021 backcountry field activities. This campsite can be accessed by several trail spurs that depart from the main trail and head north on a bench and then downhill toward No Fish Lake. This campsite is well-known by backcountry recreationists and outfitters and at the time of this field expedition, the location was utilized by two independent parties (1 party of 2; 1 party of 4 + 1 dog) in addition to our crew. Because of the popularity of this backcountry campsite, it is strongly recommended that future GLORIA crews arrive at base camp on a Monday through Wednesday, as we did, to prevent exclusion from the prime tent sites. There is an abundance of accessible water available for this campsite via No Fish Lake and its outlet stream. The lake and stream bottoms are covered in a thick layer of fine sediment causing all water filters over the course of the field expedition to become clogged. The large capacity gravity filter, which should be assessed for workability prior to future trips, was clogged beyond use at the start of the trip. A handheld Katadyn Hiker Pro filter was relied upon for the majority of the crew's water needs despite becoming heavily clogged toward the end of the expedition. It is highly recommended that additional measures be taken to protect filters from clogging (e.g., wrapping prefilter in a handkerchief or other cloth) and multiple filtration devices be available on future expeditions. The USFS does not require bear cannisters or sacks in the Pecos Wilderness, nonetheless, the crew used bear sacks provided by Bandelier National Monument to hang food and prevent wildlife access.

Each morning of the expedition, the crew hiked along the West Fork Santa Barbara Trail 25 to the Santa Barbara Divide (~1.7 km), the boundary of Rio Arriba and Mora counties as shown in Figure 1, to access routes for CHI, WCP, and NTP. There are no well-defined trails to the summits of the four peaks, but the crew found abundant game trails to follow to reach the summits.

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 the Pecos Wilderness, New Mexico are in close proximity to one another (all within ~4km), nearly all occurring on the Camino Real/ ridgeline boundary of Rio Arriba and Mora counties (Figure 1) – No Fish Peak is the one exception, occurring down slope from the ridgeline but within 1km of the backcountry base camp.

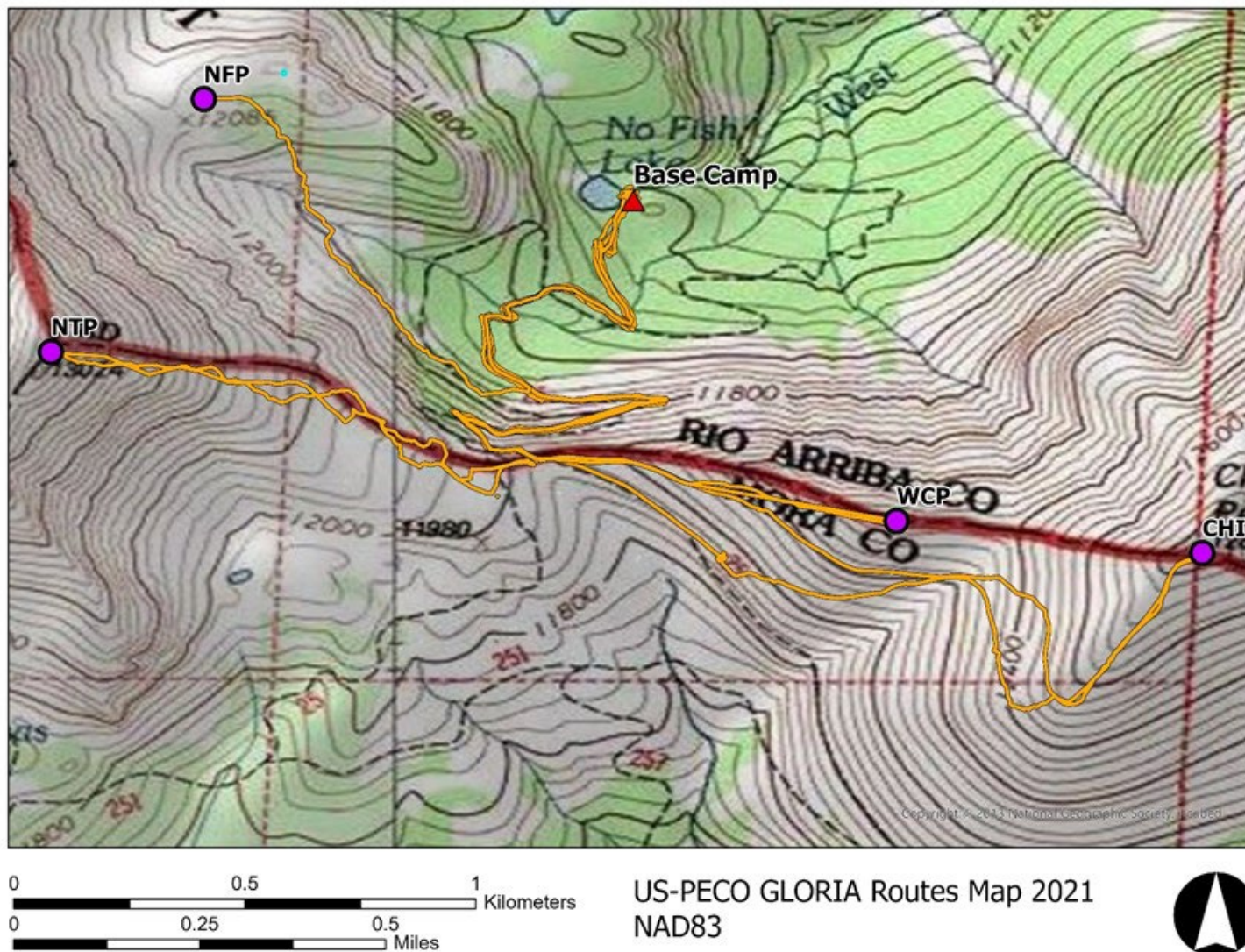


Figure 1. Locations of the four peaks in Pecos Wilderness, New Mexico, and overview of 2021 access routes to reach each summit from Base Camp. Hiking routes shown as a solid yellow line.

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

GLORIA Summit Code	Summit Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Elevation (m)	Vegetation Zone
NFP	Unnamed (referred to as No Fish Peak)	39.82383	44.3279	3,692	lower alpine/subalpine
WCP	Unnamed (referred to as West Chimayosos Peak)	39.81463	44.4482	3,782	lower/upper alpine
CHI	Chimayosos Peak	39.81393	44.5016	3,914	lower/ upper alpine
NTP	N Truchas Peak	39.81838	44.2997	3,970	upper alpine/nival

Field Sampling

The 2021 alpine growing season in the Pecos Wilderness was likely impacted by the surrounding region being under extreme and exceptional drought at the time of sampling and the previous winter (Figure 2), compared to abnormally dry conditions in the summer, and normal conditions in the winter of 2016 (Figure 3) (National Drought Mitigation Center, 2021). The effects of drought were not obvious at the time of sampling and may be due in part to the return of the North American Monsoon system to the area prior to sampling. Rain and thunderstorms were present nearly every day of sampling. In general, the drought did not appear to hinder detection of key species, but occasionally made identification more challenging and may have skewed detected species and cover values. For species with limited flowering parts, field botanists used a preponderance of evidence (form, nearby mature plants, ligule characteristics, etc.) and familiarity with certain species at different life stages where applicable. Species with lower confidence at the genus or species level were flagged on each data form using appropriate codes.

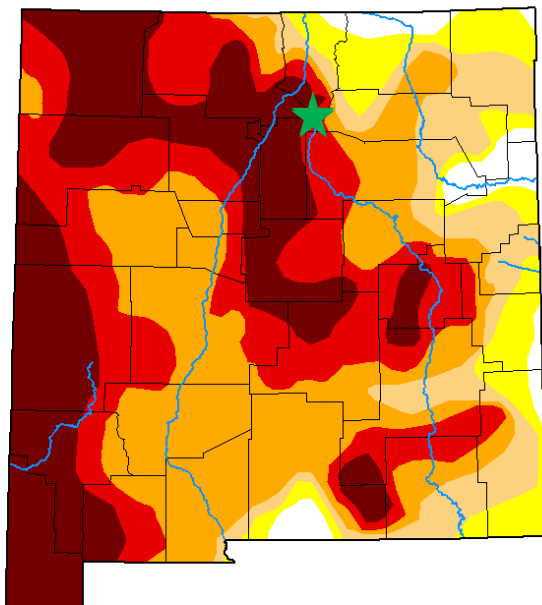
During data entry and QC, there were several instances where the 2021 crew was able to identify a species that was only identified to genus by the 2016 crew (e.g., *Vaccinium* sp.; Table 2). There were also several instances where the past crew may have misidentified a species (e.g., *Rhodiola rhodiola*, 2016 vs *Rhodiola integrifolia*, 2021), or a species was not detectable due to drought conditions based on the similar, but different species observed in 2021 vs. 2016 (Table 2). Several genera were consistently difficult to identify with confidence to species, particularly when plants were not flowering. These genera included: *Draba* spp. on all peaks; *Antennaria* spp. on NFP and NTP; and initially *Festuca* spp. on WCP.

Table 2. Species discrepancies observed between 2016 and 2021 PECO sampling events.

Species Observed 2016	Species Observed 2021
<i>Rhodiola rhodiola</i> *	<i>Rhodiola integrifolia</i>
<i>Crepis</i> sp.	<i>Hieracium gracile</i>
<i>Vaccinium</i> sp.	<i>Vaccinium scoparium</i>
<i>Gentiana</i> sp.	<i>Gentiana parryii</i>
<i>Botrychium</i> sp.	<i>Botrychium lanceolatum</i>
<i>Agoseris</i> sp.	<i>Agoseris aurantiaca</i>
<i>Ranunculus macounii</i> *	<i>Ranunculus macauleyi</i>

*suspected instance of species misidentification or difference in observed flora due to differing drought conditions in 2021 vs 2016.

U.S. Drought Monitor New Mexico



July 6, 2021
(Released Thursday, Jul. 8, 2021)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	3.62	96.38	88.20	77.12	49.34	25.67
Last Week 06-29-2021	1.04	98.96	92.88	84.87	58.80	30.47
3 Months Ago 04-06-2021	0.00	100.00	100.00	99.35	79.88	53.50
Start of Calendar Year 12-29-2020	0.00	100.00	99.97	99.59	82.26	53.20
Start of Water Year 09-29-2020	0.00	100.00	99.92	73.65	39.88	2.90
One Year Ago 07-07-2020	17.61	82.39	58.16	40.83	11.17	0.00

Intensity:

None	D2 Severe Drought
D0 Abnormally Dry	D3 Extreme Drought
D1 Moderate Drought	D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to <https://droughtmonitor.unl.edu/About.aspx>

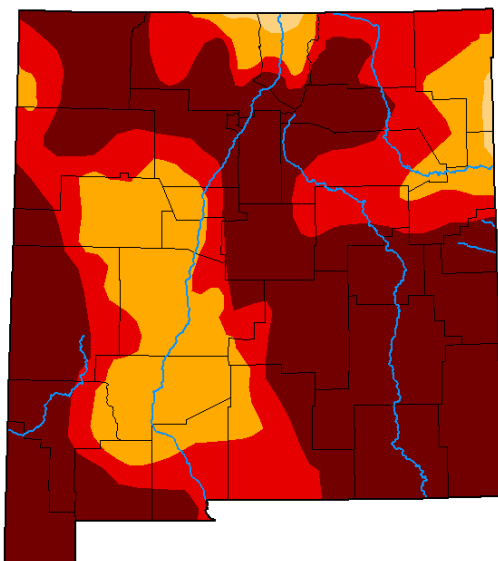
Author:

Deborah Bathke
National Drought Mitigation Center



droughtmonitor.unl.edu

U.S. Drought Monitor New Mexico



April 6, 2021
(Released Thursday, Apr. 8, 2021)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	0.00	100.00	100.00	99.35	79.88	53.50
Last Week 03-30-2021	0.00	100.00	100.00	99.35	79.88	53.28
3 Months Ago 01-05-2021	0.00	100.00	99.96	99.59	82.26	53.20
Start of Calendar Year 12-29-2020	0.00	100.00	99.97	99.59	82.26	53.20
Start of Water Year 09-29-2020	0.00	100.00	99.92	73.65	39.88	2.90
One Year Ago 04-07-2020	55.52	44.48	26.31	11.75	0.00	0.00

Intensity:

None	D2 Severe Drought
D0 Abnormally Dry	D3 Extreme Drought
D1 Moderate Drought	D4 Exceptional Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. For more information on the Drought Monitor, go to <https://droughtmonitor.unl.edu/About.aspx>

Author:

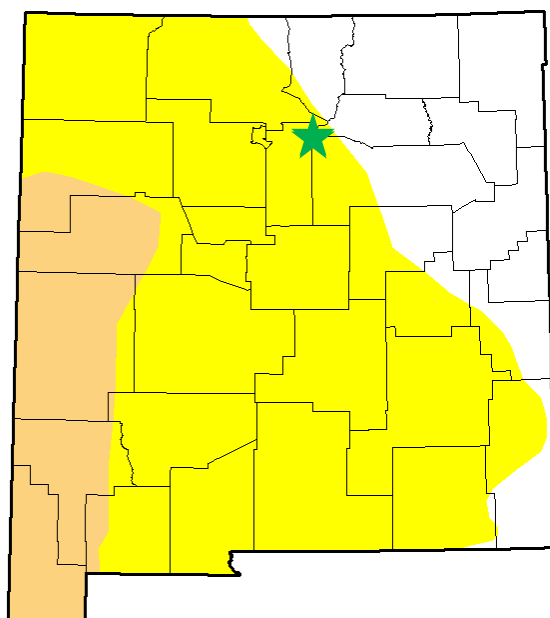
Deborah Bathke
National Drought Mitigation Center



droughtmonitor.unl.edu

Figure 2. U.S. Drought Monitor Map for New Mexico at the time of GLORIA Pecos Wilderness sampling the summer of 2021 and the previous April (early April is considered the standard time for assessing peak annual snowpack in the region (NRCS 2022)). Star shows the location of the GLORIA site.

U.S. Drought Monitor New Mexico



July 5, 2016
(Released Thursday, Jul. 7, 2016)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	22.64	77.36	15.62	0.00	0.00	0.00
Last Week 6/28/2016	22.64	77.36	15.62	0.00	0.00	0.00
3 Months Ago 4/5/2016	3.15	96.85	43.20	0.00	0.00	0.00
Start of Calendar Year 12/29/2015	73.76	26.24	0.00	0.00	0.00	0.00
Start of Water Year 9/29/2015	56.70	43.30	7.94	0.00	0.00	0.00
One Year Ago 7/7/2015	49.21	50.79	21.51	4.12	0.00	0.00

Intensity

■ D0 Abnormally Dry ■ D3 Extreme Drought
■ D1 Moderate Drought ■ D4 Exceptional Drought
■ D2 Severe Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

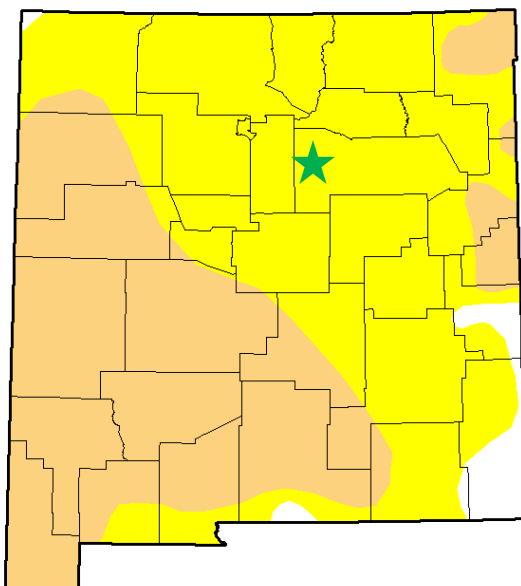
Author:

David Miskus
NOAA/NWS/NCEP/CPC



<http://droughtmonitor.unl.edu/>

U.S. Drought Monitor New Mexico



April 5, 2016
(Released Thursday, Apr. 7, 2016)
Valid 8 a.m. EDT

Drought Conditions (Percent Area)

	None	D0-D4	D1-D4	D2-D4	D3-D4	D4
Current	3.15	96.85	43.20	0.00	0.00	0.00
Last Week 3/29/2016	0.36	99.64	22.34	0.00	0.00	0.00
3 Months Ago 1/5/2016	93.64	16.36	0.00	0.00	0.00	0.00
Start of Calendar Year 12/29/2015	73.76	26.24	0.00	0.00	0.00	0.00
Start of Water Year 9/29/2015	56.70	43.30	7.94	0.00	0.00	0.00
One Year Ago 4/7/2015	19.45	80.55	62.11	18.75	0.00	0.00

Intensity

■ D0 Abnormally Dry ■ D3 Extreme Drought
■ D1 Moderate Drought ■ D4 Exceptional Drought
■ D2 Severe Drought

The Drought Monitor focuses on broad-scale conditions. Local conditions may vary. See accompanying text summary for forecast statements.

Author:

Richard Tinker
CPC/NOAA/NWS/NCEP



<http://droughtmonitor.unl.edu/>

Figure 3. U.S. Drought Monitor Map for New Mexico at the time of GLORIA Pecos Wilderness sampling the summer of 2016 and the previous April (early April is considered the standard time for assessing peak annual snowpack in the region (NRCS 2022)). Star shows the location of the GLORIA site.

Substrate hits (e.g. litter, rock, etc.) were over-estimated in some plots. Due to the familiarity with different vegetation protocols, the crew mistakenly included substrate hits underneath vascular plant hits. Unfortunately, this issue was not recognized until after sampling was completed. See Appendix B for details on how data were adjusted to account for this error.

The PECO crew sampled all 4 summits comprising the PECO GLORIA site over the course of four days. A summary of site access and set-up is provided by summit, along with notes on observations and potential sampling errors. The general timeline of sampling activities is provided below.

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. One team member 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 2021. CHI was sampled first, as it is the southeasternmost point from base camp. WCP, the second southeasternmost peak was sampled next, followed by NFP. NTP was sampled last, after the crew was well-acclimated to working at altitude and well-practiced with the GLORIA protocol.

CHI

The crew took a total of 1.25 days to sample CHI. The first day included calibration to ensure that new crew members were familiar with the GLORIA protocol and common plant species in the area. The time needed to sample plots gradually decreased as all crew members became more familiar with plants and the sampling protocol.

Site Access and Set-up

CHI is located approximately 3.5 km overland hiking from the backcountry base camp (Appendix C). It took approximately 2 hours for the entire crew to summit CHI carrying field gear. The crew started sampling at 07:30 but later retreated from the summit at 15:00 on the first sampling date due to a fast-approaching thunderstorm moving out of the southeast. Because of the threat of lightning, the crew left flagging and some sampling equipment on the summit and retreated approximately 0.8 km to trees via the same trail used to access the summit. The crew waited in the conifers until the storm passed and began to hike back to base camp at 16:20. Two members of the crew revisited the summit on the second sampling day to complete the remaining SASs and retrieve gear.

The crew used CHI as a calibration peak, including site set-up, to ensure consistency in plant ID and plot sampling across researchers. Nails were missing from North 1,3 and North 3,1 1-m² quadrats but the crew was still able to set up each plot without too much difficulty.



Sampling quadrats on CHI in Pecos Wilderness, New Mexico (July 2021; photographed by Andrea Schuhmann).

Observations and Sampling Errors

The crew members assigned to plots consistently entered a “s” on the data sheet when they were confident to species, and a “g” when they were confident to genus – this contradicted standard protocol (Pauli et al. 2015) but instructions were given for this team to continue the same method of recording to prevent inconsistencies and further confusion. This same crew underestimated litter cover – only estimating litter based on dead plant material that was not connected to a live plant. Protocol defines litter as “dead plant material” (Pauli et al. 2015), therefore, using plot photos, minor adjustments were made to litter counts for CHI plots in the database. Litter was a minor cover component across CHI and adjust cover did not exceed 1.1%. *Draba* species identification was consistently difficult for all crews, especially in the absence of flowers which made up the majority of plants observed. There was some internal discussion regarding identification of *Oreoxis bakeri* vs *Podistera eastwoodiae* at this summit and all other summits.

But it was later confirmed by Patrick Alexander to be *Oreoxis bakeri* based on range and bisected, trident shaped bractlets.



Draba aurea observed on Chimayosos Peak, Pecos Wilderness, New Mexico (July 2021; photographed by Patrick Alexander).

It was also observed and noted later on the first day of sampling that one crew member appeared to be experiencing mild altitude-related symptoms that affected their data recording abilities. Minor adjustments were made to data sheets when necessary and this crew member was closely monitored and instructed to rest – their symptoms did not persist beyond that day. Throughout the sampling period, the crew adopted a standard procedure where a more experienced botanist or plant ecologist was paired with less experienced data recorders. 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 post-trip.

There was some isolated soil disturbance around the summit point but it was difficult to determine the source of disturbance (e.g., animal-induced). Bighorn sheep and ground squirrel activity was observed in addition to two hikers observed summiting the peak from the south side of the summit on the day of sampling. No clear or distinct trail/trails exist to the summit though recreational access is most likely always from the south end of the peak. One crew member observed 4 black swifts flying at eye level while facing north and west from the summit of CHI –

black swifts are considered a species of conservation concern by numerous state and federal agencies throughout its range, including in New Mexico.

WCP

The crew took one full field day to sample WCP, beginning at 05:45 (two members of crew completed the remaining SAS's on CHI from 06:00 to 07:45) and finishing at 13:05. The crew quickly gathered gear and exited the summit due to an approaching storm.

Site Access and Set-up

The crew accessed WCP by heading due east of the Santa Barbara Divide via an unofficial trail/game trail along the ridgeline and the boundary of Rio Arriba and Mora counties. Two nails were missing from 1x1 m² plots, one from East 1,3 and 1 from South 1,3.

Observations and Sampling Errors

Stunted trees (*Picea englemanii*) and shrubs (*Potentilla fruticosa*, *Salix nivalis*) were present, though a rare component of the plant community composition of WCP. The crew observed rodent burrows, pika vocalizing, and bighorn sheep scat, with all aspects showing evidence of some animal activity. Drabas continued to provide difficulties in species determinations and *Festuca saximontana* vs. *Festuca brachyphylla* provided some initial confusion but the crew later keyed the grass to *Festuca brachyphylla*, the more commonly observed species, with a few rare occurrences of *Festuca saximontana*.



Draba heilii basal rosette and flowering stem documented on CHI (left) and WCP (right) (July 2021, Patrick Alexander)

NFP

The NFP Peak took 1 day to sample, with the crew arriving at 08:50 and completing the peak by 15:00. The crew had initially attempted to summit NTP via a ridgeline approach accessed from

the Truchas Lakes area. The crew determined that technical climbing was required for this approach, therefore, the plan to sample NTP was aborted and the crew returned to the Santa Barbara Divide area and opted to hike to NFP.

Site Access and Set-up

The crew accessed NFP via a short section of trail 25 and then traveled off-trail along the side slope to access the bench where NFP was located at the base of a steep rocky ridgeline. Travel time was approximately 45 minutes to reach the summit from base camp. This peak is the closest to base camp (though it does require more off-trail navigation) and has the most accessible and secure tree cover in case of inclement weather. There were no difficulties noted with plot and site set-up.

Observations and Sampling Errors

This site is positioned on a bench within a bowl surrounded on the west and north by a steep rocky ridgeline, protecting the site from the prevailing winds characteristic of the other summits. There was a strong graminoid (e.g., *Carex rupestris*, *Calamagrostis purpureascens*, *Festuca brachyphylla*), shrub (e.g., *Potentilla fruticosa*, *Vaccinium scoparium*), and tree (*Picea englemannii*, *Abies concolor*, *Juniperus communis*) component to the site's vegetative cover compared to the other summits. *Antennaria* spp., almost exclusively vegetative, proved difficult to determine to species. Additionally, it is suspected that the crew may have occasionally confused *Trisetum spicatum* and *Calamagrostis purpureascens* due these species looking vegetatively similar, though *Calamagrostis purpureascens* was considered the more commonly encountered species. Cover estimates and pointing hits for *lichens on soil* were suspected to have been overestimated for several 1-m² quadrats due to all lichen cover being counted (i.e., included epilithic lichen cover with *Lichens on soil* cover), however, upon reexamination of plot data and photos, no apparent discrepancies could be discerned and therefore no changes were made to the final database.

NTP

NTP took 1 day to sample. The ascent from the Santa Barbara Divide to the NTP summit was approximately 1 km; the crew left camp at 0400, summited NTP by 0530 and completed sampling by 11:00. NTP is the most exposed summit, with the closest protective tree cover nearly 1 km away – for this reason, the crew opted for the earliest wake-up time and approach to make it less likely we would be on the summit as afternoon thunderstorms were developing.

Site Access and Set-up

NTP was expected to be the most difficult peak to access due to its steep ascent and lack of a defined trail. Backpackers camping at the No Fish Lake base camp area informed our crew that they felt unsafe at times summitting NTP due to the steepness and rockiness of the terrain – this

report led us to attempt an alternative approach from the Truchas Lakes area that ultimately failed due to the technical climbing requirement. We instead opted to sample NFP on that day rather than approaching NTF from the Truchas Lakes area. Our final day of sampling we approached NFP from the east-face via the Santa Barbara Divide. We did not follow a defined trail to the summit, but rather created numerous switchbacks using game trails and areas of denser vegetation – we did our best to avoid unstable patches of scree. All crew members were instructed prior to starting our ascent that they could back out at any time if they felt unsafe, but we were all able to summit and descend without any issues. All 3,3 quadrats do not have nails which initially made it difficult to arrange quadrats. The missing nails are due to a lack of enough hardware in 2016 – nails should be placed on next sampling visit. Plot photos from 2016 were utilized to arrange quadrats and grids in the absence of these nails.

Observations and Sampling Errors

There was no marked trail to access NTP but it is clear that this peak, one of New Mexico's top 3 highest peaks, receives regular traffic from recreationalists. There were four hikers observed summiting the peak on the day of sampling. The area also receives regular grazing by Bighorn sheep (6 adults and 2 lambs observed downslope on day of sampling), several graminoids showed signs of grazing. Though pika were not observed within the sampling area, they were audible and evidence of small mammal browsing was apparent in some locations. The crew was highly efficient surveying this peak; very few species were new to the researchers at this point and many of the species identification and methodological difficulties had been worked out at this point.

Notes for Future Sampling

General Tasks Prior to 2026 GLORIA Sampling Event

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

Logistical Notes for Future Sampling Events

1. The survey crew was comprised of 7 people which turned out to be a highly efficient crew size: 4 team members focused on 1m² cover plots – 2 people identified plants and 2 recorded; 2 team members set up grid and plots and completed photographs and disturbance worksheets; and 1 team member completed summit area sections.
2. Given the mistakes made in following the protocol, we recommend conducting more training on the GLORIA methods prior to field work and additional oversight of field crew during the first day(s) of sampling. The team for this expedition was made up of team members from multiple states and locations, therefore, the typical half day training on CSU campus was not possible. All crew members received an electronic copy of the GLORIA sampling manual (Pauli et al. 2015) several weeks in advance of the field expedition and were instructed to review the sampling protocol. Team leader, Andrea Schuhmann received a day of training and instructions from Sarah Marshall, practicing in the alpine off Trail Ridge Road in Rocky Mountain National Park in an easily accessible location to begin learning the plants likely to be encountered in GLORIA plots. While the plant community at PECO is different, many of the more common alpine species occur in alpine areas of both parks. For the team members that could not attend an in-person field training occurred at base camp the night before sampling commenced.
3. It is not possible to make reservations at the No Fish Lake backcountry camp site. It is advisable that future crews access the camp site on a weekday (Monday – Wednesday preferable) and anticipate other backpackers utilizing the location.
4. Ensure that the crew is clear on visual estimation of top cover vs. total cover, and calibrated in estimation up front. While the crew covered this at the beginning of the sampling event, there were still several instances where crews recorded top cover values less than total cover, potentially due to working at altitude for extended periods of time.
5. Ensure that the crew is clear on not including substrate “hits” (e.g., litter, rock, etc.) beneath vascular plant hits.
6. Stress the importance of clear, legible writing on field forms and/or consider digital data collection where possible or more efficient. The 2021 crew did not attempt digital data collection, partly due to being in the backcountry for the entire field sampling period. It may be worth testing digital data collection options prior to the next sampling event in 2026. However, it is worth noting that when the crew attempted to bring along digital references (e.g., *Flora Neomexicana*) via cell phone in place of heavier books – those references were lost when a phone took an accidental swim in a wetland.
7. As time passes from site set-up, the GLORIA database plant names are increasingly different from the latest nomenclature in the *Flora Neomexicana* (Allred and Jercinovic 2020) and *Flora of Colorado* (Ackerfield 2015) used by earlier crews. An update to the latest *Flora of Colorado* is in progress at present, and a new edition of the flora will likely be available before the next sampling event. The 2020 crew also utilized the keys in *Sedges of Colorado* (Wingate 2017) for *Carex* species and *Grasses of Colorado* (Shaw 2008) for grasses.

8. The crew had no cell phone reception for almost the entire duration of the field sampling period, including the base camp site and on most summits (there was some spotty reception on CHI and NTP). The crew had 2 two-way Spot-X satellite messenger devices for morning and evening check-ins with emergency contacts. In the limited cases where the crew split up, each smaller group would carry a Spot-X unit.
9. It is highly recommended that additional measures be taken to protect filters from clogging (e.g., wrapping prefilter in a handkerchief or other cloth) and multiple filtration devices be available on future expeditions.
10. Bring nails to replace plot markers that were missing, including CHI North 1,3 and North 3,1 and WCP East 1,3 and South 1,3 1-m² quadrats.

Conclusion

The 2021 PECO survey crew was able to successfully sample all 4 GLORIA summits at a rate of 1 days per summit, spread across a total of 7 days including both travel and field work. Efficiencies were gained by dividing the crew into 3 smaller teams on several occasions, allowing the first team to setup the summit grid and take photographs, the second team to assess plots and the third team or individual to complete summit area section assessments.

The 2021 alpine growing season was likely influenced by extreme drought conditions. In general, this did not appear to hinder detection of key species, but occasionally made identification more challenging and may have affected observed vegetation cover and slightly skewed detected plants toward later-blooming species like members of the *Asteraceae* family.

When analyzing the data for 2021, it will be important to note that ground or substrate elements (e.g., litter, rock, etc.) were likely included as “hits” beneath vascular plant “hits.” Unfortunately, this issue was not recognized until after sampling was completed and was likely propagated across all sites. Crew members and the crew leader were familiar with, and therefore confused by other line-point-intercept methods that include substrate “hits” beneath vascular plants when assessing cover characteristics. A note was made (#5) in the Logistical Notes for Field Sampling Section, to emphasize this element of the sampling protocol to future crews. Adjustments were made to the 2021 field substrate data following consultation with Erin Borgman (NPS). A full explanation of the reasons, approach, rules, and limitations for these adjustments can be found in Appendix B.

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Appendix A: US-PECO 2021 Field Log

Date	Peak	Persons	Activities	Notes
7/6/2021		Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, and Chris McCormick (all CNHP); Kara Fox and Ella Kasten (NPS)	Travel to Santa Barbara developed USFS campground for car camping overnight.	6.5 hr drive from Fort Collins; 2.5 hr drive from Bandelier National Monument
7/7/2021	CHI	Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, Chris McCormick, Kara Fox, Ella Kasten, and Patrick Alexander	Site set-up, completed all (16) 1m ² cover plots, (5 of 8) SAS, and all photos completed; quickly retreated from summit due to pop-up thunderstorm out of the southeast; QC and plant ID at camp	Departed camp at 05:30; arrived at CHI at 07:30. Departed CHI around 15:00 due to approaching thunderstorm. Stopped in tree line and waited for storm to pass to prevent open exposure to lightning down trail. Continued hiking down trail at 16:20, arrived at camp at 17:00.
7/8/2021	CHI & WCP	Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, Chris McCormick, Kara Fox, Ella Kasten, and Patrick Alexander	CHI: completed remaining 3 SASs. WCP: site set-up, (16) 1m ² cover plots, (8) SAS, and all photos completed; QC and plant ID at camp	Departed camp at 04:30; group arrived at Divide at 5:15 and split in two groups. Team of five arrived at WCP at 5:45. Team of two arrived at CHI at 6:00 and completed sampling by 07:45 and rejoined larger group at WCP. WCP completed by 13:05pm – just in time to avoid the thunderstorm that emerged from the east behind CHI.
7/9/2021	NFP	Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, Kara Fox, Ella Kasten, and Patrick Alexander	Site set-up, (16) 1m ² cover plots, (8) SASs; and all photos completed; QC and plant ID at camp	Departed camp at 04:00 am, attempted south approach to NTP from Truchas lakes – arrived at lakes ~06:00. Determined technical climbing required for this approach – aborted NTP and opted to return to Divide and hike to NFP. Arrived at 08:50. Completed NFP at 15:00 and returned to camp by 15:45.
7/10/2021	NTP	Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, Chris McCormick, Kara Fox, Ella Kasten, and Patrick Alexander	Site set-up, (16) 1m ² cover plots, (8) SASs; and all photos completed; QC and plant ID at camp	Departed camp at 04:00, summited NTP at 05:30. Completed summit by 11:00. Returned to camp by 12:20.
7/11/2021		Andrea Schuhmann, Teru Funabashi, Tai Mei Chang, Chris McCormick, Kara Fox, Ella Kasten	Hike out of backcountry. Travel home.	Broke down camp and departed base camp at 05:00 am. Arrived at trailhead and Santa Barbara Campground at 08:30 am.

Appendix B: Adjustment of 2021 field substrate data

Background: The substrate counts using the point intercept method for the 1x1 m quadrats in the 2021 PECO field assessment should not be considered reliable. While reviewing the field data, it was determined that often, though not systematically, field observers counted substrate hits (e.g., solid rock, scree, bare ground, etc.) that occurred beneath the vascular plant hits. Though common in other field protocols using the line-point intercept method, this approach does not accurately follow the GLORIA protocol where substrates are not counted beneath vascular plant hits. Therefore, substrate hits were overrepresented by the 2021 field data. *The 2021 vascular plant hits were unaffected by this issue and counts should be considered reliable.*

Approach: A visually simulated point intercept count using quadrat photos (taken with 1x1 m grid frames) was made to adjust overcounted substrate hits. High resolution quadrat photos (ranging typically from 18,000 – 25,000 KB) were examined grid by grid for the entire quadrat to count visually simulated vascular plant hits and substrate hits. Vascular plant hits were separated into two categories: “V_dense” where a stroke hit multiple species and “V_single” where a stroke hit a single species; substrate hits included: solid rock, scree, lichen, bryophyte, bare ground, and litter.

Assessment of photo-based resampling accuracy: The 2021 field data vascular plant hits (considered reliable) were compared to the photo-based vascular plant hits to assess the general accuracy and reliability of the photo-based resampling. Photo-based vascular plant hits were calculated as follows:

$$2 \times (V_{dense}) + (V_{single})$$

Because alpine vegetation is low-growing and rarely forms more than two layers of overlapping plants, Vdense was assumed to represent two hits of vascular plants. The difference between the estimated number of vascular plant hits and the field-based counts informed the general accuracy of the photo-based resampling.

Rules for Data Adjustment: Values from the field and the photo-based resampling were compared and finalized based on the following rules:

1. Keep the original field-based vascular plant counts.
2. Keep the field values if the resampled values are higher than the field data. This indicates the quadrat does not represent an instance where the substrate was overcounted in the field.
3. If the resampling results in a reduction of only 1 or 2 hits for the substrates, use the field data unless otherwise justified.
4. If the difference between the field data and the photo-based data is more than 10%, check the quadrat photos, 2016 data, and other evaluation factors to justify adjustments.
 - a. For solid rock and scree, also look at a sum of the two categories.
 - b. Check the quadrat photo to see if the field data is reasonable.
 - c. Compare adjusted counts to 2016 and 2021 field data.
 - d. If the difference cannot be justified, keep the field data.

Limitations

1. It is difficult to distinguish scree vs. rocks from the photos. Assessing rock and scree combined rather than individually helped mitigate this issue when comparing photo-based counts to field data.
2. Quadrat photos were sometimes taken at an angle to avoid shadow, or large rocks distorted the angle of the grid frame resulting in a higher error rate of estimated vascular plant hits compared with the 2021 field data.

Justification for use of the adjusted point intercept data: The overcounting of surface hits in the 2021 field sampling resulted in 8,047 total hits compared to 6,664 for 2016 (Table 1) across all PECO summits. Based on the GLORIA sampling protocol, total top cover of vascular plants and total substrate hits should be close to 100 or just beyond (when there are multiple plants counted in a single hit). The mean top cover hits were 104 for the 2016 data while the 2021 field data were dramatically higher with a mean of 125 hits. Based on a comparison of 2016 and 2021 quadrat photos (e.g., No Fish Peak E1,3 and W3,3), this difference was not due to an increase in multiple vascular plant hits, but rather, the overcounting of substrate. The photo-based resampling of the 2021 substrate data resulted in data more comparable with 2016 field data. The descriptive statistics of the total number of hits among three datasets (2021 field, 2021 adjusted, 2016) clearly shows that 2021_adjusted led to the similarly distributed pointing hits compared to 2016 data.

Table B-1. Summary statistics for the total number of hits for 2021 field data, 2021 photo-adjusted data, and 2016 field data.

Measure	2021_field	2021_adjusted	2016
Mean	125.73	105.02	104.13
Standard Error	2.18	0.61	0.51
Median	121.5	103.5	103
Mode	119	101	102
Range	77	26	23
Minimum	99	99	98
Maximum	176	125	121
Sum	8,047	6,721	6,664

Appendix C: US-PECO 2021 Route Map to Base Camp

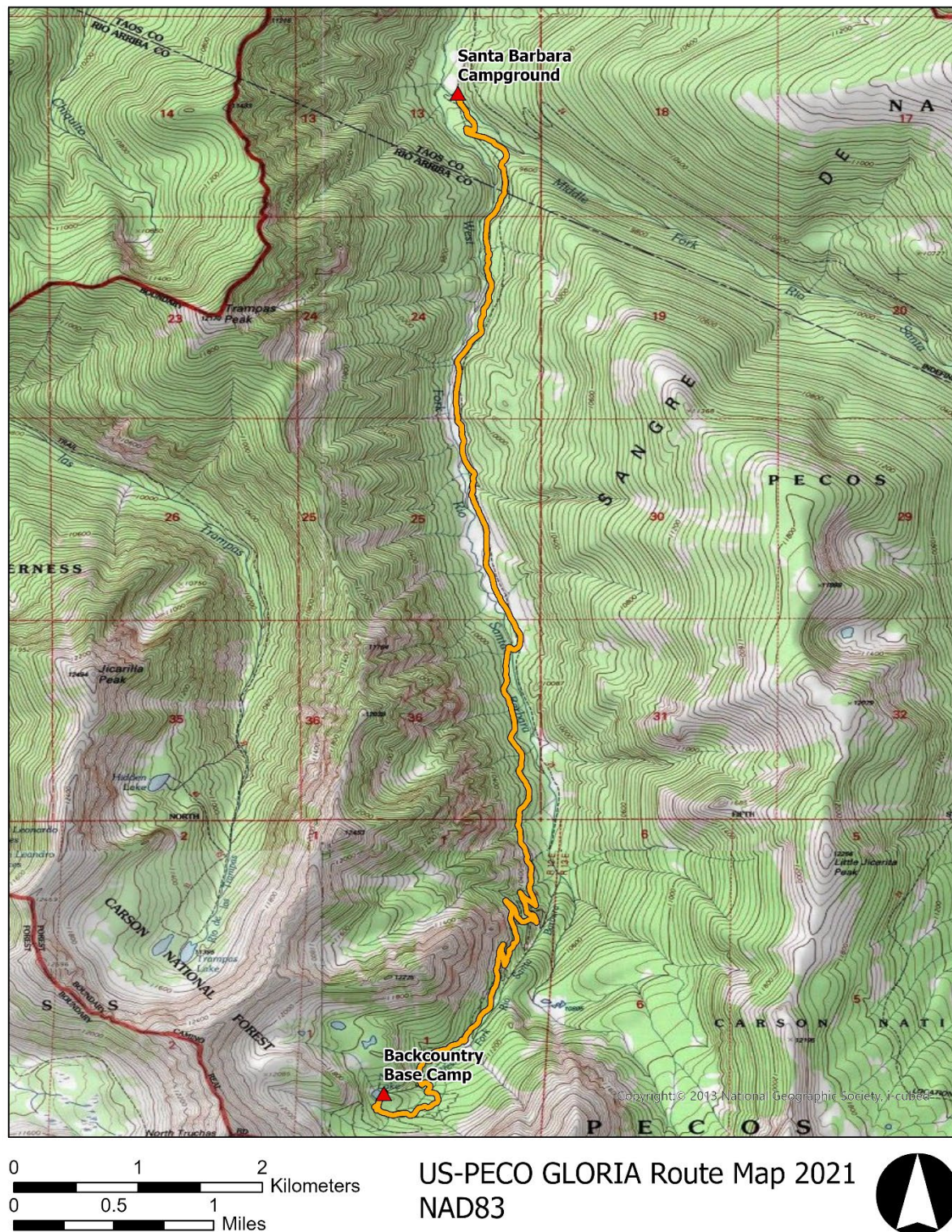


Figure C-1: Overview of 2021 hiking route from Santa Barbara Campground to Backcountry Base Camp.

Appendix D: U.S. Forest Service Contacts and Carson National Forest, Forest Supervisor Letter of Support

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Forest Supervisor
U.S. Forest Service
Sante Fe National Forest
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Michael Lujan
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United States
Department of
Agriculture

Forest
Service

Santa Fe National Forest

Supervisor's Office
11 Forest Lane
Santa Fe, NM 87508
505-438-5300
Fax: 505-438-5390

File Code: 2100
Date: June 28, 2021

Andrea Schuhmann
Ecologist/Zoologist
Colorado Natural Heritage Program
Colorado State University
Warner College of Natural Resources
General Services Building Room 244
Fort Collins, Colorado 80523-1475

Dear Andrea:

I am providing approval to Colorado State University for the proposed GLORIA monitoring project in the Pecos Wilderness on the Santa Fe National Forest. This project is a continuation of research which began in 2016. This year the work consists of: *replacing shallow temperature loggers this year (4 per summit, or a total of 16 loggers), and not collecting any soil samples. The loggers are shallow, and will be gently excavated/replaced in their existing holes.* The Santa Fe National Forest has completed a categorical exclusion under category 7 CFR 1b.3(a)(3) – Inventories, research activities, and studies, such as resource inventories and routine data collection when such actions are clearly limited in context and intensity – for this project.

Please continue to coordinate project activities with the forest's watershed program manager, Micah Kiesow – micah.kiesow@usda.gov as needed.

Sincerely,

DEBBIE
CRESS
DEBBIE CRESS
Forest Supervisor

Digitally signed by
DEBBIE CRESS
Date: 2021.06.28
13:41:39 -06'00'



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Appendix E: Area Outfitters Contacted for Pack Support

Red River Stables

Website: <https://www.redriverstables.com/>

Contact: Dirk and Kathy Neal

Contact Email: rrstables03@gmail.com

575.754.1700

Rio Grande Stables

Website: <https://www.riograndestables.net/>

Phone: 888.259.8267

Roadrunner Tours

Website: <https://www.nancyburch.com/>

Contact: Nancy Burch

Phone: 575.377.6416

H&A Outfitters, Inc.

Website: <https://www.nmbiggamehunting.com/>

Contact: Andy Salgado

Contact Email: andy@nmbiggamehunting.com

New Mexico Council of Outfitters and Guides

Website: <https://www.nmoutfitters.com/>

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.



National Park Service
U.S. Department of the Interior

[Natural Resource Stewardship and Science](#)

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