ESTABLISHING GLORIA IN THE LEMHI MOUNTAINS, IDAHO, FOR LONG-TERM MONITORING OF ALPINE VEGETATION





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ABSTRACT
The alpine zone represents an ecosystem at a climate extreme; one that is very temperature dependent and predicted to be a sensitive indicator to climatic changes. GLORIA (Global Observation Research Initiative in Alpine Environments) is a program to establish and maintain a worldwide, long-term monitoring network for comparative study of climate change impacts on mountain vegetation and its biodiversity. The GLORIA monitoring program aims to document vegetation changes over time in alpine environments using plots established on a set of summits that represent a low to high alpine elevational gradient within a target region. In 2018, we established the first GLORIA target region in Idaho, in the Lemhi Mountains. Plot establishment and baseline sampling was completed on three summits – Bruce Canyon Peak, Spring Mountain, and Sheep Mountain, all located south of the historic mining town of Gilmore. GLORIA summits ranged from 3066 m (10050 ft) for Bruce Canyon Peak, to 3312 m (10865 ft) elevation at Sheep Mountain, a gradient extending from a short distance upslope of the treeline ecotone to the regional upper alpine.

Sampling recorded a total of 82 vascular plant species at the 3 GLORIA summits, including 1 tree, 2 shrub, 13 graminoid, and 66 forb species. Spring Mountain had the most floristic diversity with 66 species, followed by Bruce Canyon Peak with 44 species, and Sheep Mountain with 35 species. Bruce Canyon Peak had the highest, Sheep Mountain the lowest, and Spring Mountain an intermediate amount of vegetation cover. Vegetation cover on each summit was dominated by graminoid species, specifically *Carex elynoides* at Bruce Canyon Peak, *Calamagrostis purpurascens* with lesser amounts of *Carex elynoides* and *Carex rupestris* at Spring Mountain, and *Carex rupestris* at Sheep Mountain. Forb diversity was relatively high at each summit, but with only a few species contributing more than trace cover. Spring Mountain had a few *Taraxacum officinale* plants, the only non-native plant species recorded at a GLORIA site. Two species of conservation concern in Idaho were recorded at the GLORIA summits. *Cymopterus douglassii* was one of the more widespread and common forbs at Sheep Mountain, but absent from the other two summits. A solitary, small *Pinus albicaulis* was found on the eastern upper slope of Spring Mountain tucked beneath a shelf of exposed bedrock. A few alive and dead 2018 *Pinus albicaulis* seedlings were observed on Sheep Mountain.

High elevation ecosystems in Idaho are important for watershed, wildlife, biodiversity, aesthetic, and other values. GLORIA monitoring is relevant for Idaho because alpine habitat is relatively limited in distribution and extent in the state. Loss/contraction of alpine habitat due to climatic changes has the potential to seriously impact Idaho's high elevation biota. GLORIA monitoring can provide land managers and others interested in high elevation ecosystems a better understanding of the relationships linking climate change and alpine biodiversity. It provides a program to help document, monitor, and assess possible long-term shifts and vulnerabilities to alpine vegetation in the Lemhi and other nearby mountain ranges. This information has the potential to inform and help guide future conservation activities benefiting Idaho's iconic alpine landscapes.

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INTRODUCTION

The alpine zone represents an ecosystem at a climate extreme; one that is very temperature dependent and predicted to be a sensitive indicator to climatic changes (Pauli et al. 2015 and references cited within). GLORIA (Global Observation Research Initiative in Alpine Environments) is a program to establish and maintain a worldwide, long-term monitoring network for comparative study of climate change impacts on mountain vegetation and its biodiversity (Pauli et al. 2015). The GLORIA monitoring program aims to document vegetation changes over time in alpine environments using plots established on a set of summits that represent a low to high alpine elevational gradient within a target region. Standardized sampling protocols collect data in an arrangement of nested plots positioned within the top 10 vertical meters of the summit. Monitoring focuses on changes in plant species richness (number of species), plant species composition (species loss or gain), plant species abundance (percent cover and frequency), soil temperature, and snow cover (indirectly through soil temperature measurements).

The first GLORIA sites were established in Europe in 2001. The program soon expanded to all other continents except Antarctica and now includes target regions in at least 40 countries (Global Observation Research Initiative in Alpine Environments 2001 - 2018). In the United States, GLORIA sites have been established in California, Montana, Wyoming, Colorado, Nevada, and Oregon. In 2018, we established the first GLORIA target region in Idaho, in the Lemhi Mountains, in the east-central part of the state. Plot establishment and baseline sampling were completed on three summits in the Spring Mountain-Sheep Mountain area. A fourth planned summit was not done due to lack of time. This report summarizes GLORIA establishment in Idaho and the baseline data collected in 2018.

High elevation ecosystems in Idaho are important for watershed, wildlife, biodiversity, aesthetic, and other values. Monitoring data collected using GLORIA provides a means to discern trends in species diversity needed to document, assess, and predict changes/losses in biodiversity and other threats to alpine ecosystems. The monitoring information can provide land managers and others interested in high elevation ecosystems a better understanding of the relationships linking climate change and changes in alpine vegetation patterns and associated biodiversity. Monitoring and documenting changes can also serve to inform and guide potential conservation activities in local alpine environments. GLORIA data collected in the Lemhi Range will be relevant to the conservation of alpine habitats in other regional mountain ranges too. As part of the GLORIA network, monitoring data from the Lemhi Range has the potential to be viewed and evaluated in a larger context and contribute to efforts to better understand climate-related changes in alpine ecosystems at an international scale. Future conservation and mitigation efforts aimed at limiting biodiversity and habitat loss in alpine environments will benefit from this understanding.

PROJECT AREA

The Lemhi Mountains are located in east-central Idaho and form one of the longest and highest mountain ranges in the state. They rise above the Snake River Plain and extend northward for approximately 160 km (100 mi), varying from approximately 16 to 24 km (10 to 15 mi) wide along this length. Elevations range up to 3718 m (12,197 ft) at the summit of Diamond Peak, with four other named peaks rising above 3353 m (11,000 ft). Most high peaks repeatedly supported large glaciers in the past (Ruppel and Lopez 1988). Alpine habitats are restricted to a narrow band along the crest of the range above approximately 3050 m (10,000 ft) elevation.

The GLORIA summits are all located within an approximately 4.5 km (2.8 mi) long section of the central part of the Lemhi Mountains, south of the historic mining town of Gilmore (Figure 1). The nearest town is Leadore in the upper Lemhi River Valley, located approximately 35 km (22 mi) to the north.

The Lemhi Mountains are a fault block range that lie within the Cordilleran fold and thrust belt at the northern end of the Basin and Range geologic province (Link and Janecke 1999). Different geologies dominate the northern and southern portions of the Lemhi Range. In general, Proterozoic-age quartzites belonging to the Yellowjacket, Swauger, Gunsight, and related Formations of Belt Supergroup rocks dominate the northern half; compared to Paleozoic sedimentary rocks dominating the southern half of the Lemhi Range (Ruppel and Lopez 1988). The GLORIA summits are located near the center of the range, at the northern end of the section dominated by Paleozoic rocks. Proterozoic strata form most of the geology beginning just a few miles further north (Rember and Bennett 1979, Ruppel and Lopez 1988).

Geology at the three GLORIA summits is mapped as Three Forks and Jefferson Formations, and Laketown Dolomite (Ruppel and Lopez 1988). Silurian age Laketown Dolomite rocks consists of light-gray weathering, finely to medium-crystalline dolomite characterized by a sparkling appearance in freshly broken surfaces. It is exposed in many places along the eastern flank of the central Lemhi Mountains. The Three Forks and Jefferson Formations are both of Devonian age, the former consisting of yellowish and pinkish to light-gray, very finely crystalline limestone, silty limestone, and calcareous siltstone; the latter of brownish to light or dark grayish dolomitic sandstone or other dolomitic and non-dolomitic rocks. In the Lemhi Range, both the Three Forks and Jefferson Formations are best exposed in the Gilmore area. Surface rocks at all three GLORIA summits appeared to be the Laketown Dolomite component of this geologic unit.

Climate in the east-central Idaho mountains has both coastal and continental influences giving rise to cold, wet winters, and warm, dry summers (Ross and Savage 1967). Prevailing winds are from the west. January is the coldest month and July the warmest. Annual precipitation at the GLORIA summits is probably similar to the 853 mm (34 in) reported for Meadow Lake, a high subalpine site located a few miles north of Sheep Mountain (cited in Urbanzyk and Henderson 1994). The majority of moisture falls during the winter months as snow. Summers are dry, with precipitation largely limited to occasional rain showers. Ecological classification places the Lemhi Mountains within the Beaverhead Mountains Section of the Middle Rocky Mountains Province (McNab and Avers 1994).

Alpine soils in the central Lemhi Mountains predominately formed as colluvium and slope alluvium from limestone and dolomite. Landforms include cirque headwalls, ridges, gentle to steep mountain slopes, and saddles. Rubble land and rock outcrops tend to cover a large percentage of areas near cirque headwalls, and lesser amounts on other landforms. Soils generally classify to Inceptisol and Mollisol orders of soil taxonomy. Textures range from silt loam to sandy loams, with 35 to 85 percent gravels and cobbles. Mineralogy of the soils is dominated by the carbonatic limestone. Depth to bedrock varies from 50 cm (20 in) on summits and shoulders to greater than 150 cm (59 in) on mountain slopes, swales, and saddles (Carla Rebernak, MLRA Soil Survey Leader, Natural Resources Conservation Service, 2018, pers. comm.).

The Spring Mountain and Bruce Canyon Peak GLORIA summit areas are mapped as the Alpine Graminoid Fritz Ecological Type (Map Unit TEU 8), a classification unit occurring on windswept mountain summits in the alpine zone that supports low-growing alpine graminoid vegetation on Fritz series soils (U.S. Forest Service 1997). This ecological unit has a cryic soil temperature regime and xeric soil moisture regime. Winds that remove a portion of the snowpack, desiccating winds, and minimal summer rains contribute to the prevalence of dry soil conditions in late summer and autumn. A part of the Spring Mountain GLORIA summit also overlaps the Low Alpine Forb Cryochrepts, loamy-skeletal Ecological Type (Map Unit 1280), a classification unit that supports low-growing alpine forb communities (U.S. Forest Service 1999). This ecological unit has a cryic soil temperature regime and udic soil moisture regime. The Sheep Mountain GLORIA summit is mapped as the Low Alpine Forb Cryochrepts, loamy-skeletal Ecological Type (Map Unit TEU 9) that has characteristics similar to Map Unit 1280 (U.S. Forest Service 1997).

Land use in the central Lemhi Mountains includes historical mining, livestock grazing, and recreation. Prospecting for mineral deposits in the area began in the 1860s, although the earliest noteworthy discoveries were not made until 1880 (Ruppel and Lopez 1988). Mining operations fizzled out in the area in the late 1880s when deposits at the larger mines were exhausted. However, mining activity resumed in the early 1900s with the discovery of new deposits of lead, silver, and other precious metals in the Spring Mountain and Texas Mining Districts. One result of this renewal was establishment of the town of Gilmore in 1903. Operations declined after about 1925 and most mining in the area ended a few years later. The three GLORIA summits occur within the boundaries of the Spring Mountain and Texas Mining Districts (Ruppel and Lopez 1988). None of the GLORIA summits have evidence of past or recent mining disturbance, although remnants of small mines or prospects occur within approximately 0.8 km (0.5 mi) of each site. The network of dirt roads in the area was originally constructed to access the mines and prospects. Two of the three GLORIA summits established in 2018 are located within the boundaries of the Sheep Mountain Research Natural Area (RNA).

Seasonal livestock grazing occurs at lower elevations, but has been historically insignificant in the vicinity of the GLORIA summits due to the lack of perennial surface water in the alpine zone. Although most alpine areas in the central Lemhi Mountains are not closed to livestock they receive little if any use. Most current activity in the central Lemhi Range centers on recreation, and at high elevations generally involves the use of motorcycles and all-terrain or other high-clearance 4-wheel drive vehicles. Steep, narrow, rough roads up the Squaw Creek and Spring Mountain Canyon drainages cross the Lemhi crest and are popular rides that provide access to a section of alpine habitat in the Spring Mountain-Big Windy Peak area. The GLORIA summits range from approximately 0.3 to 2.2 km (0.2 to 1.4 mi) from points along this road system. Although no maintained hiking trails occur near the GLORIA summits, the road network is used by a small number of hikers and climbers to access high ridges and peaks via cross-country travel.

GLORIA SUMMITS

A GLORIA target region consists of a set of four (minimum three) summits that represent an elevation gradient from the upper treeline ecotone upslope to the uppermost alpine vegetation zone (Pauli et al. 2015). The target region is the mountain range or area in which the selected summits are located. Selecting a set of suitable summits is the first requirement when establishing a new GLORIA target region. Selected summits need to meet a set of six standard criteria (Pauli et al. 2015):

(1) Summits need to lie outside areas of active volcanism.

(2) Summits should be exposed to the same local climate. Ideally, climatic differences between summits are caused only by their different altitudinal positions.

(3) Summits should be composed of similar bedrock. A mix of contrasting bedrock types should be avoided to alleviate differences in species richness and composition that could be substrate-related.

(4) Summits should not be in areas obviously altered or affected by human interference or land uses such as mining, livestock grazing, or excessive recreation.
(5) Summits should be of “moderate” geomorphologic shape - very steep, as well as flat plateau-like summits are unsuitable for the application of GLORIA protocols. Ideally, summits should have a more or less conical shape that can accommodate plots on all sides (north, south, east, west aspects). The terrain needs to be safe to access and sample without the use of technical climbing equipment.
(6) Prevalent vegetation on the chosen summits should be representative for the typical species occurring in the respective elevation belt. Summits dominated by solid rock, unstable scree fields, or large boulder fields, should be avoided.

Reconnaissance trips in 2017 and 2018 selected four summits suitable for GLORIA in the Lemhi Mountains target region. Three of these were established in 2018 (Figure 2). All are positioned along the crest of the Lemhi Range, a divide separating the Little Lost River drainage to the west and Birch Creek Valley to the east. Selected summits encompass the low to high elevational alpine gradient of the Lemhi Range and also meet the climatic and bedrock consistency, summit shape, researcher safety, human-related disturbances/impacts, and representative vegetation patterns criteria required for GLORIA. We also considered accessibility when selecting the GLORIA summits, choosing summits requiring less than a 2-hour hike from the nearest road. Having relatively accessible summits facilitated logistics in 2018 and will help future resampling efforts be carried out on schedule.

METHODS

GLORIA uses a standardized monitoring protocol with sampling and data collection taking place in a series of plots located within the top 10 vertical meters below, and 100 horizontal meters distance from the HSP (Figure 3). GLORIA data collection includes a set of four mandatory sampling protocols and several optional, supplemental protocols. Required sampling includes:

1. The collection of percent cover data and frequency counts for all vascular plant species and ground surface attributes using a 1m x 1m quadrat positioned within a 3m x 3m sample grid. The grids are positioned 5 vertical meters from the HSP in each cardinal direction (N, E, S, W). Four 1m x 1m quadrats are sampled within each grid. Thus, data are collected in a total of 16 quadrats, 4 in each of the cardinal directions.
2. The division of each summit into 8 Summit Area Sections (SAS); 4 sections in the upper 5 vertical meters from the HSP, and 4 sections in the lower 5 vertical meters. An inventory of all vascular plant species and their assignment to 1 of 5 abundance categories (very rare, rare, scattered, common, dominant) is made within each SAS. Percent cover for ground surface attributes is also estimated for each SAS.
3. The burial of 1 soil temperature data logger 10 cm deep within each 3m x 3m sample grid. This results in the placement of 4 data loggers for each summit. Data loggers are programed to take a temperature reading once an hour, all day, every day (battery life is 4 - 5 years). In general, this design is meant to provide information on snowpack duration and climatic conditions for the summit’s four cardinal directions (Pauli et al. 2015). Measured soil temperature series enable calculations of temperature indices such as mean, minima, maxima and temperature sums, annually and/or for certain periods. Growing season length can also be calculated by determining dates of snow accumulation and snow melt (Pauli et al. 2015).
4. The taking of a large set of photographs meant to aid in relocating the various plot markers during future revisits, provide visual documentation of the vegetation and terrain, and be useful for photo monitoring purposes.

The GLORIA Manual (Pauli et al. 2015) also includes several optional, supplemental data collection methods. Following the lead of the Great Basin GLORIA program, we chose to incorporate the 10m x 10m Square Plot supplemental method into the Idaho GLORIA program. One strength of this method is to provide a larger sampling area than the 3m x 3m grids to compare diversity patterns between the four cardinal directions (Pauli et al. 2015). It also provides more quantitative data compared to the SAS abundance categories. Line-pointing data collected with this method can be used to calculate percent cover values for individual plant species as well as their total top cover value.

All plot establishment and data collection methods are described in detail in the GLORIA Field Manual (Pauli et al. 2015). All azimuths were determined using a compass set to 12° east declination. The following section provides a general overview of how we established the GLORIA plots.

Plot establishment

High Summit Point: The HSP typically marks the highest point on the summit and is the starting point for all measurements used to establish the GLORIA site. An “X” etched into a piece of solid rock marks the HSP at each summit.

Establishing the cardinal direction lines: Our first measurements were to locate points 5 vertical meters and 10 vertical meters below the HSP in each of the four cardinal directions (geographic N, E, S, W). We used a measuring rod expandable to a height of 8 m and a clinometer to determine these points. We set the rod to a height of 6.64 m (corresponding to the needed 5 m elevation drop + 1.64 m, the eye-level standing height of the person reading the clinometer). Standing at the HSP, the person with the clinometer determined the 5 m drop in vertical elevation for each of the cardinal directions by guiding the person with the rod to the point where the clinometer read 0° (level) when directed at the 6.64 m mark on the measuring rod. A repeat of this procedure determined the 10 vertical meter drop point. The only difference was that the person with the clinometer stood at the newly established 5-m point instead of the HSP. We laid colored string from the HSP to the 5-m and 10-m points for each of the cardinal directions.

Establishing the 3m x 3m grids along the cardinal direction lines: The 5-m point along the cardinal direction line serves as the reference point to establish the 3m x 3m quadrat cluster grids. The grids can be positioned on either the right side or left side of the direction line. We made an arbitrary, left or right side decision at each 5-m cardinal direction point. However, terrain or habitat conditions dictated the choice for us in cases where one side of the line was too steep or erosive to sample safely, or where one side was largely rock with little or no vegetation compared to the other side. In these cases, we chose to sample the less erosion-prone side of the line, or the side with higher vegetation cover.

Delineating the upper and lower Summit Areas and the Summit Area Sections: The summit area is divided into separate upper and lower parts. The upper Summit Area encompasses the upper 5 vertical meters around the summit; the lower Summit Area encompasses the zone 5 to 10 vertical meters below the summit. The upper and lower Summit Areas are then each subdivided into four Summit Area Sections.

Delineating the upper Summit Area - The upper Summit Area can be delineated once all the cardinal direction strings and their associated 3m x 3m grids are in place. The lower right and lower left corner points of each 3m x 3m grid are used to guide placement of the string line that delineates the upper Summit Area. A string around the summit connects these eight corner points to delimit the downslope perimeter of the upper Summit Area. The corner points are connected around the summit in straight surface lines. Although the upper Summit Area is at the 5 m level at the 3m x 3m grids, it often lies above the 5 m contour line between the grids.

Delineating the lower Summit Area - The previously marked N, E, S, and W 10-m points form the corner points for the lower Summit Area. A string is laid to connect these four corner points, forming a straight line between each corner. This string delineates the downslope perimeter of the lower Summit Area. The lower Summit Area is therefore the area between the strings that delineate the downslope perimeters of the upper and lower Summit Areas.

Delineating the Summit Area Sections – The upper and lower Summit Areas are each subdivided into four Summit Area Sections. This is done by placing a string in a straight line from the HSP to the 10-m lower Summit Area perimeter string in the NE, SE, SW, and NW (intercardinal) directions. This arrangement subdivides the upper and lower Summit Areas into four sections each: NE-SE, SE-SW, SW-NW, and NW-NE.

Establishing the 10m x 10m Square Plots: This is a supplementary method applied within the Summit Area in each of the four cardinal directions. Each of the four plots overlaps into portions of both the Upper and Lower Summit Areas. The lower corner point of the 3m x 3m grid represents the midpoint of the 10m x 10m plot. Measurements from this midpoint are used to fix the upper and lower corner points of the plot. We used 2, pre-measured 20-m lengths of cord to establish the plot perimeter; with each piece of cord covering two of the 10-m sides of the plot. Both cords start from the same point and end at the same point diagonally opposite their start point. A 10-m section of each 20-m cord is pre-marked every meter beginning and ending 0.5 m from the cord ends. A separate 10-m cord marked at 1-m intervals is placed between opposing meter marks on the perimeter cords and used to guide sampling and the collection of line-pointing data in the plot.

Marking summit reference points: We marked important plot reference points with outdoor-rated chrome-color paint sprayed as a circular patch onto a rock positioned at (or in some cases close to if no rock present) the reference point. Painted reference points at each summit included the HSP; all 5-m and 10-m points along the principal cardinal direction lines; all corners for the 3m x 3m grids; all points where the intercardinal lines intersect the 5-m and 10-m Summit Area Sections lines; and at each soil temperate data logger burial location. We also hammered 5-inch aluminum nails into the ground at all 5-m and 10-m points along the principal cardinal direction lines. The HSP was further marker by etching a “X” in exposed bedrock or the protruding part of a partly buried rock at the point.

RESULTS

Plot establishment and baseline sampling were completed for three GLORIA summits in the Lemhi Mountains of Idaho, 16 - 19, July 2018 (Table 1). Lack of time prevented GLORIA being established on the fourth planned summit. The Idaho GLORIA team consisted of Anne Halford (Idaho Bureau of Land Management), Lynn Kinter (Idaho Department of Fish and Game), Jessica Irwin and Allison Busier (U.S. Forest Service Rocky Mountain Research Station), Jodi Brandt (Boise State University), Beth Corbin and Paul Allen (Idaho Native Plant Society), Rose Lehman (Caribou-Targhee National Forest), and Michael Mancuso (Mancuso Botanical Services). GLORIA summits ranged from 3066 m (10050 ft) to 3312 m (10865 ft) elevation, a gradient extending from a short distance upslope of the treeline ecotone to the regional upper alpine. No peaks in the Lemhi Range or elsewhere in Idaho reach elevations high enough to have a nivial zone. GLORIA summit slopes ranged from nearly flat to approximately 30°. The GLORIA summits are located on lands administered by either the Salmon-Challis NF or the Caribou-Targhee NF.

Monitoring data were recorded on a set of standardized GLORIA field data sheets, including Forms 0, 1, 2, 3, 4, and 6-S (Appendix 1). Sampling at each summit included: (1) the collection of percent cover and frequency data for all vascular plant species and ground surface attributes recorded in 1m x 1m quadrats within a 3m x 3m sampling grid (Form 2); (2) an inventory of all vascular plant species within each SAS and assigning an associated abundance category (Form 3); and (3) the collection of line-pointing data for all vascular plant species and ground surface attributes recorded in 10m x 10m square plots (Form 6-S). To collect soil temperature data, HOBO MX Tidbit 400 (manufactured by Onset) data loggers were buried at each summit (Form 4). In addition, an extensive set of photographs taken at each summit helps document the vegetation and other summit and landscape features.

The location of each GLORIA summit was mapped (Figure 2) and documented with GPS coordinates (Appendix 2). Additional GPS points and notes regarding plot establishment and data collection were taken at each summit to facilitate future resampling efforts (Appendix 2). Monitoring data recorded on field forms (Appendix 1) were converted to spreadsheet format (Appendix 3) to facilitate data compilation, synthesis, and future uploading into the GLORIA database. The 2018 GLORIA photoset consists of >180 photographs that will be uploaded into the GLORIA program database.

Sampling recorded a total of 82 vascular plant species at the 3 GLORIA summits, including 1 tree, 2 shrub, 13 graminoid, and 66 forb species (Table 2). Spring Mountain had the most floristic diversity with 66 species, followed by Bruce Canyon Peak with 44 species and Sheep Mountain with 35 species. Not sampling the north aspect due to its cliff-like topography contributed to the relatively low floristic diversity recorded for Sheep Mountain. Three plant families, Asteraceae with 20 species (24%), Poaceae with 13 species (16%), and Brassicaceae with 8 species (10%) accounted for half (50%) of the overall recorded plant species richness. Eighteen species (22%) were recorded on all 3 GLORIA summits, while 27species (33%) occurred on 2 summits, and 37 species (45%) were limited to 1 summit (Table 2). Six genera were especially well represented at the GLORIA sites with at least 4 species each, including *Antennaria*, *Arenaria* (*sensu lato* with *Arenaria* and *Minuartia*), *Draba*, *Poa*, and *Townsendia*. Spring Mountain had a few *Taraxacum officinale* (common dandelion) plants, the only non-native plant species recorded at a GLORIA site.

Vegetation cover was highest on Bruce Canyon Peak, lowest on Sheep Mountain, and intermediate on Spring Mountain. Vegetation cover on each summit was dominated by graminoid species, specifically *Carex elynoides* at Bruce Canyon Peak, *Calamagrostis purpurascens* with lesser amounts of *Carex elynoides* and *Carex rupestris* at Spring Mountain, and *Carex rupestris* at Sheep Mountain (Tables 3, 4, 5). Contributions from other graminoid species tended to be relatively minor. Forb diversity was relatively high at each summit, but with only a few species contributing more >1% cover. Aspect-related species richness patterns were inconsistent between the three summits, with the most taxa recorded on the south aspect for Bruce Canyon Peak, the north aspect for Spring Mountain, and the west aspect for Sheep Mountain. It was not uncommon for species to show variations in presence-absence and/or abundance between north, south, east, and west aspects.

Sampling 1m x 1m quadrats in the 3m x 3m grids recorded 52 (63%) of the 82 plant species associated with the three summits (Table 3). The majority (77%) of species always averaged <1% cover across north, south, east, and west aspects of a summit. The 13 (23%) species that averaged >1% cover on at least one summit tended to have cover values of <3%. The only exceptions were *Calamagrostis purpurascens*, *Carex elynoides*, and *Carex rupestris* which averaged ≥5% cover in quadrat sampling on at least one summit. *Phlox pulvinata* and *Carex rupestris* were the only species to average >1% cover in quadrat sampling on all three summits. *Calamagrostis purpurascens*, *Carex elynoides*, and *Minuartia obtusiloba* averaged >1% cover on two summits. Tree and shrub species were not recorded in any 1m x 1m quadrats. Quadrat sampling found scree to be the most common surface feature attribute, averaging >50% cover at each summit. Vascular plant cover averages ranged from 36% at Bruce Canyon to 25.2% at Sheep Mountain. All other surface features averaged <8% cover.

Summit Area Section sampling assigned abundance categories “very rare” or “rare” to the majority of plant species at each summit (Table 4). Relatively few species were rated “common” in at least half of the SAS plots on a summit. *Carex elynoides*, *Carex rupestris*, and *Phlox pulvinata* were the only species rated “common” in a majority of SAS plots at more than one summit. The “dominant” abundance category was not assigned to any species on any summit.

Data collection in the 10m x 10m square plots recorded 62 (76%) of the 82 plant species associated with the three summits (Table 5). The majority (60%) of species always had <1% cover for the summit when averaged across north, south, east, and west aspects. At Bruce Canyon Peak, the 17.4% cover average for *Carex elynoides* was at least four times greater compared to all other species. *Phlox pulvinata* averaged 4.2% cover, the highest value compared to the other five forb species with ≥1% average cover on the summit. At Spring Mountain, *Calamagrostis purpurascens*, *Carex elynoides*, and *Carex rupestris* combined to average 16.9% cover for the four aspects. In comparison, all other species averaged a combined 14.9% cover, including 2.4% cover for *Phlox pulvinata*, the highest value for any forb species. *Carex rupestris* averaged 12.1% cover and *Phlox pulvinata* 5.2% cover for south, east, and west aspects (north not sampled) at Sheep Mountain. All other species combined to average 4.4% cover. Scree was the most common surface feature attribute in all 10m x 10m square plots. Average scree cover on a summit was always more than twice the average of all other surface types combined.

Two plant species of conservation concern were recorded at the GLORIA summits. *Cymopterus douglassii* (Douglass’ wavewing) was one of the more widespread and common forb species at Sheep Mountain, but absent from the other two summits. A solitary whitebark pine approximately 0.3 m tall occurred on the eastern upper slope of Spring Mountain, tucked in a small protected alcove beneath a shelf of exposed bedrock. Another solitary small whitebark pine was observed <10 m outside the GLORIA summit zone on the north aspect of Spring Mountain. A few alive and dead 2018 whitebark pine seedlings were observed on Sheep Mountain. Persistence of those still alive seemed doubtful.

Plant identification was relatively straightforward for most species after we spent time reviewing the local flora before sampling each summit. Taxa that presented at least occasional identification problems included *Elymus scribneri* versus *Elymus elymoides, Packera werneriifolia* versus *Senecio fremontii*, the four species of *Minuartia*, and species of *Poa*. For data entry and consistency purposes, all *Elymus* were assigned to *Elymus scribneri* even though in some cases plants may have been *Elymus elymoides*. Similarly, all *Packera*/*Senecio* were assigned to *Packera werneriifolia* for data entry and consistency purposes even though in some cases plants may have been *Senecio fremontii*. It is possible some *Minuartia obtusiloba* may have been mistaken for another *Minuartia* species. *Poa* was the most problematic genus. Questionable identifications were recorded as *Poa* sp. on data sheets. Each summit had a small number of taxa identified to the genus rank only due to the lack of reproductive structures needed for confident identification. Only a few voucher specimens were collected (Table 2). They will be deposited in the Stillinger Herbarium at the University of Idaho.

DISCUSSION

The main goals of the GLORIA program are to: (1) accumulate a standardized, quantitative dataset on plant species richness, composition, and abundance, and for ground surface attributes; and on soil temperature and snow cover period in mountain systems world-wide; (2) quantify changes in species and vegetation patterns through long-term monitoring in permanent plots; (3) quantify changes in the abiotic environment such as the amount of unvegetated surface and the temperature regime; (4) build globally applicable and comparable indicators of climate change-driven impacts on alpine vegetation and biodiversity; (5) assess the risks of biodiversity losses and ecosystem instability due to climate change; and (6) provide information for developing conservation strategies and actions needed to mitigate climate-induced threats to biodiversity in alpine habitats (Pauli et al. 2015).

The Idaho GLORIA team was able to establish and collect baseline data at three of the four GLORIA summits planned for the Lemhi Mountain target region in 2018. We hope to complete the fourth summit in summer 2019. One candidate is an unnamed minor summit located approximately 1.3 km (0.8 mi) south of Sheep Mountain at 3164 m (10380 ft), an elevation intermediate between Sheep Mountain and Spring Mountain. It is recommended that GLORIA summits be resampled at intervals of 5 to 10 years (Pauli et al. 2015).

Alpine habitats in Idaho are confined to mountains in the central and east-central parts of the state. Several factors led to the selection of the central Lemhi Mountains for the first Idaho GLORIA target area: (1) a 2017 reconnaissance identified several summits in the Spring Mountain area as potentially suitable for GLORIA; (2) previous alpine vegetation classification work in the Sheep Mountain area (Urbancyzk and Henderson 1994) made quantitative plant community and other basic floristic information available that is lacking for most other alpine areas in Idaho; (3) presence of the Sheep Mountain RNA, a designation that recognizes the area's diverse alpine biota, confers extra land management protection, and encourages non-destructive research opportunities (Rust et al. 1996); (4) the presence of a few old mining roads that provide rough, but relatively ready access to the alpine, an uncommon advantage in a state where nearly all alpine areas are roadless; (5) exceptional support from the Caribou-Targhee and Salmon-Challis National Forests, the land managers for high elevation areas in the Lemhi Range.

An alpine plant community classification project in the Sheep Mountain area in the early 1990s makes the RNA one of the few alpine locations in Idaho with a quantitative plant community dataset (Urbanczyk and Henderson 1994). The classification identified eight alpine plant communities and described their apparent habitat preferences. Based on this classification, vegetation at the three GLORIA summits correspond to three different community types – the *Carex elynoides* community type at Bruce Canyon Peak; the *Calamagrostis purpurascens* – *Carex elynoides* community type at Spring Mountain; and the *Carex rupestris* community type at Sheep Mountain. In general, the classification found the *Carex elynoides* community type to occur in areas with a moderate slope, some snow accumulation, well-developed soil, and not directly exposed to winter winds. The *Calamagrostis purpurascens* – *Carex elynoides* community type occurs on sites more exposed and drier compared to the *Carex elynoides* type. The *Carex rupestris* community type occupies the highest, driest, most exposed sites that are likely blown snow-free in winter. These sites have shallow, rocky soil derived from dolomite and relatively sparse vegetation (Urbanczyk and Henderson 1994).

The high elevation vascular plant flora for the Sheep Mountain area is relatively well documented. Plant lists for the area are associated with the Sheep Mountain RNA establishment record (Rust et al. 1996), the Sheep Mountain alpine classification project

(Urbanczyk and Henderson 1994), and a project that resampled a subset of the original alpine classification study plots (Mancuso and Lehman 2016). A comprehensive list based on these sources, plus our 2018 GLORIA data collection, consists of 143 vascular plant species (Appendix 4) for the general Sheep Mountain area. GLORIA sampling recorded a total of 82 species, including five species not previously included in the earlier Sheep Mountain area lists - *Allium* sp., *Arenaria kingii* var. *compacta*, *Cirsium scariosum*, *Cystopteris fragilis*, and *Townsendia leptotes*. A few plant species recorded on the Idaho GLORIA summits are more or less restricted to alpine/arctic habitats, including *Eritrichium nanum*, *Minuartia austromontana*, and *Saxifraga oppositifolia*. However, most species are not limited to the alpine zone. Examples include species such as *Linum lewisii* and *Pseudoroegneria spicata* with distributions extending down to valley elevations; or *Bupleurum americanum*, *Draba oligosperma*, and *Ivesia gordonii* which can be found from the montane to alpine zones. Quite a few species occurring in the GLORIA plots, such as *Calamagrostis purpurascens*, *Minuartia obtusiloba*, and *Phlox pulvinata* occur in both subalpine and alpine habitats. A subset of these, including *Lloydia serotina*, *Smelowskia calycina*, *Tetraneuris grandiflora*, and *Cymopterus douglassii* are largely limited to high subalpine and alpine environments.

Two species of conservation concern were recorded during GLORIA sampling. *Cymopterus douglassii* is an east-central Idaho endemic known from a few populations in the Lost River Range and from a population in the Sheep Mountain area in the Lemhi Range (Idaho Natural Heritage Program 2018). It is a U.S. Forest Service Region 4 Sensitive plant species for both the Salmon-Challis NF and the Caribou-Targhee NF. We found *Cymopterus douglassii* to be relatively common within the Sheep Mountain GLORIA summit zone. Obvious, immediate threats to its habitat in the area were absent. Whitebark pine is a federal Candidate species for listing under the Endangered Species Act (U.S. Fish and Wildlife Service 2011), and also a Sensitive species for the Salmon-Challis NF and the Caribou-Targhee NF. A solitary, small whitebark pine was found on the eastern upper slope of Spring Mountain tucked beneath a shelf of exposed bedrock. A few alive and dead 2018 whitebark pine seedlings were observed on Sheep Mountain. Stands of whitebark pine formed the upper treeline downslope of each GLORIA summit. One possible response to climate change is the upslope migration of whitebark pine into currently unsuitable alpine areas. This could have important conservation implications regarding the long-term persistence of whitebark pine in the east-central Idaho mountains. GLORIA plots are now available to monitor, detect, and document this possibility in the Lemhi Range. GLORIA monitoring information also has relevance to the conservation of other plant and animal species that use Idaho's alpine habitats at least seasonally. As one example, Jim Cane (USDA ARS, Bee Biology & Systematics Lab, Logan, Utah) conducted an initial pollinator inventory at Bruce Canyon Peak while the GLORIA team was collecting vegetation data at this summit.

Sheep Mountain and Bruce Canyon Peak are located within the Sheep Mountain RNA, a designation that confers some protection and special management consideration. The objective of the Sheep Mountain RNA is to contribute to a national network of ecological areas dedicated to research, education, and maintenance of biological diversity by providing representation of alpine turf communities (Rust et al. 1996). The main management objective is to maintain the natural conditions and processes associated with the RNA in as near an undisturbed condition as possible without direct human impacts. The GLORIA project fits the type of research study encouraged by the RNA system. Establishing GLORIA in the Sheep Mountain area provides an opportunity for the RNA to serve as a regional reference for the study and long-term monitoring of ecological changes in an alpine ecosystem. Being part of the GLORIA program also positions Sheep Mountain RNA to be included in large-scale, worldwide analysis regarding climate change effects on alpine ecosystems.

Alpine habitats are predicted to be especially vulnerable to ecological changes related to climate change (Korner 2003, Gonzalez et al. 2010). GLORIA monitoring is relevant for Idaho because alpine habitat is relatively limited in distribution and extent in the state. Loss/contraction of alpine habitat due to climatic changes has the potential to seriously impact Idaho's high elevation biota. GLORIA monitoring information can provide land managers and others interested in high elevation ecosystems a better understanding of the relationships linking climate change and alpine biodiversity. GLORIA provides a program to help document, monitor, and assess possible long-term shifts and vulnerabilities to alpine vegetation in the Lemhi and other nearby mountain ranges. This information has the potential to inform and help guide future conservation activities benefiting Idaho's iconic alpine landscapes.

The effort to establish a GLORIA monitoring program in Idaho has been a collaborative partnership that includes the U.S. Forest Service, Idaho Bureau of Land Management, Boise State University, U.S. Fish and Wildlife Service, Idaho Natural Heritage Program, and Mancuso Botanical Services. Plot maintenance and future resampling of GLORIA in the Lemhi Mountains target region will require similar commitment, coordination, and collaboration efforts. Any possible expansion of GLORIA to additional target regions in Idaho will also depend on continued collaborative partnerships.

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