A New GLORIA Target Region in the Sierra Nevada, California, USA; Alpine Plant Monitoring for Global Climate Change

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INTRODUCTION

The earth experiences climate change whether from human-meditated atmospheric effects or as a response to natural drivers. High mountain ecosystems are both sensitive to climate variability and prone to be early indicators of effects that will ripple through distant ecosystems. To better anticipate effects of climate change, and to promote effective mitigation and adaptation, we must accurately measure and understand responses of mountain biota. The Global Observation Research Initiative in Alpine Environments (GLORIA), headquartered in Vienna, Austria, is an international monitoring program focused on responses of high-elevation plants to longterm climate change. GLORIA's multi-summit approach capitalizes on the intercomparability of a highly standardized monitoring protocol and the fact that alpine environments are similar and widely distributed worldwide. To date, multi-summit target regions have been installed in Europe and other continents; the Sierra Nevada site installed in summer 2004 is one of three completed in North America.

METHODS

The GLORIA program prescribes a standard protocol for surveying and measuring floristic composition and diversity that is used in all GLORIA multi-summit target regions (Pauli et al. 2004):

1. Select four mountain summits within a single bioclimatic region. Elevations of the summits progress from treeline to the nival zone (fig 1). For the Sierra Nevada target region, we chose three summits of Mt Dunderberg (in the central, eastern Sierra near Bridgeport, CA), and an unnamed fourth summit on the Sierra Nevada crest near Tioga Pass (figs 2, 3). Summit elevations ranged from 3322 – 3749 m; surface area varied 3-fold due to shape of summits.
2. Lay out a nested monitoring design on each summit, photo documenting, and monumenting corners (figs 4, 5). The design emphasizes a geographic hierarchy of plot sizes, from 0.01m plots to 5m and 10m elevational sections on each summit.

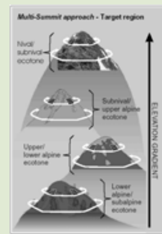

Fig 1.

Fig 2.

Fig 3a. Dunderberg; 3b. Granite Lks

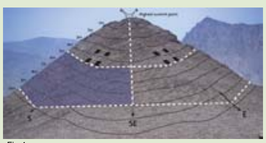

Fig 4.

Fig 5.

3. Compile a species list; measure specified variables for plant cover, frequency, and abundance within the nested regions of each summit (fig 6). Place temperature dataloggers on major aspects (fig 7).
4. Archive plant specimens with herbaria, and archive photos and data with GLORIA international data archive (figs 8, 9).
5. Remeasure every 5 years.

Fig 9.

Fig 6.

Fig 7.

Fig 8.

RESULTS

Overall Species Diversity

We identified 65 taxa in total from the Sierra Nevada GLORIA target region plots (fig 10). In total 18 families were represented. The most diverse groups were composites (15 taxa), grasses (11 taxa), mustards (8 taxa), and sedges (5 taxa). There were 42 dicot and 16 monocot taxa present. We found no alien species.

Summit	Elev	N taxa	N unique taxa
Dunlow	3322	38	18
Granite	3341	36	8
Dunmid	3570	13	3
Dunhigh	3749	22	5
Total		**65**	

Fig 10.

Elevational Diversity

The two lowest summits had the highest species diversity as well as the most unique taxa (figs 10, 11). The lowest summit represented an elevational-transitional flora: most of the 18 taxa unique to this summit had affinities to lower elevational communities. The lowest summit was also at the edge of the *Pinus albicaulis* forest and the herbaceous species associated with the pine community had little overlap with those on upper summits (fig 12). Of the five taxa that occurred only on the highest summit, two (*Artemesia arbuscula* and *Athyruim alpestre*) have substantial range at lower elevation; two (*Draba lemonii* and *Ivesia lycopodoides*) have some range lower in the alpine zone; only *Poa keckii* stands out as truly alpine.

Plant Name	DunlLo cover	Gran cover	DunMid cover	DunHi cover
		RANKS:		
Chrysothamnus parryi sp. monocephalus	1	5	2	x
Pinus albicaulis	2	9		x
Leptodactylon pungens	3	7	1	
Arenaria kingii	4	x		
Elymus elymoides ssp. californicus	5	6	3	2
Ribes cereum	6	2		
Muhlenbergia richardsonis	7	10		
Ivesia shockleyi var. shockleyi	8			
Senecio canus	9			
Astragalus whitneyi	10			
Calamagrostis purpurascens	x	1		
Phlox condensata	x	3		1
Carex phaeocephala		4	6	7
Carex multicostata		8		
Erigeron pygmaeus	x		4	5
Erigeron compositus	x	x	5	
Sphaeromeria cana			7	
Erysimum capitatum var. capitatum	x	x	8	
Cryptantha flavoculata	x		9	
Hulsea algida			10	
Astragalus kentrophyta var. danaus	x			3
Ivesia lycopodioides ssp. lycopodioides				4
Carex helleri		x		6
Artemisia arbuscula				8
Trisetum spicatum		x		9
Erigeron algidus		x	x	10
Eriogonum ovalifolium var. ovalifolium	x	x		
Arabis platysperma var. howellii	x	x		x
Achnatherum pinetorum	x	x		
Astragalus purshii	x			
Castilleja nana	x			
Festuca brachyphylla ssp. breviculmis		x		
Draba breweri		x		
Oxyria digyna		x		x

Fig 11. Abundant species on four Sierra GLORIA summits, ranked by percent cover into 10 classes (1 is highest, 10 is lowest) based on abundance in 8 area sections per summit. "X" indicates presence at lower abundance than ranked taxa.

Aspect Diversity

We found no significant differences in species diversity among slope aspects in total number of taxa (North – 48; East – 49; South – 51; West – 48), although some taxa were confined to aspect (fig 13).

Aspect	Condition	N taxa	N taxa confined	Representative taxa
N, E	Cool	55	5	*Silene sargentii, Hulsea algida, Artemesia arbuscula*
S, W	Warm	60	10	*Arabis pulchra, Phoenicaulis cheiranthoides, Lomatium torreyi*

Fig 13.

Fig 12.

Biogeography & Implications of Climate Change to Alpine Vegetation

Vegetation on the Sierra summits had two major structural elements:

1) Shrubs, subshrubs and graminoids with a broad elevational and geographic range in montane and subalpine zones of the Sierra Nevada and Great Basin. Examples include *Elymus elymoides*; *Chrysothamnus parryi*, *Leptodactylon pungens*, *Muhlenbergia richardsonis, Ribes cereum, and Artemesia arbuscula* (fig 14).

2) A second vegetation structural component present on all summits was tight groundhugging mats of alpine cushion plants composed of species such as *Phlox condensata, Astragalus kentrophyta, Erigeron pygmaeus, Draba densifolia,* and *Senecio werneriifolius*.

All summits had many additional species occurring at very low densities in patchy or scattered distributions; more than 80% of species on all summits were present at cover values of far less than 1%. These species also fell into more or less distinct groups, those with exclusively alpine distributions, and those with broader elevational distributions in the Great Basin and elsewhere. Examples of alpine species include: *Arabis platysperma var. howellii*, *Erigeron algidus, E. ovalifolium, Ivesia shockleyi var. shockleyi*. Examples of species with broad elevational distributions include: *Arenaria kingii, Castilleja nana, Cryptantha flavoculata,* and *Silene sargentii* (fig 15).

The highest summit had a decidedly reduced component of the Great Basin species. However, the lowest summits, although missing some alpine species, were clearly within range for supporting most of the species that form the characteristic mat vegetation of the highest summit and much of the exclusively alpine floristic component of the higher summits.

Based on these observations, the species that stand out as likely candidates for being lost from the local flora if conditions on the high peaks come to resemble those of the lower summits would be *Poa keckii* and *Hulsea algida* (fig 16). If upward migration of vegetation zones exceeds 500m, there would be no alpine zone in this region, and there would probably be losses of much of the exclusively alpine floristic component.

Further, an advance of pines upslope could cause local reduction of the Great Basin component that, apparently, does not persist in understory situations. We found pine seedlings on all but the mid peak. With an assumption of 200 meters upward migration per degree of warming, 2-3°C could put the highest summit within a forest zone.

Fig 14a. *Leptodactylon pungens* and *Ribes cereum*; 14b. *Artemesia arbuscula*

Fig 15a. *Erigeron algidus*, 15b. *E. ovalifolium*

Fig 16. *Hulsea algida*

REFERENCE:

Pauli, H., M. Gottfried, D. Hohenwallner, K. Reiter, R. Casale, G. Grabherr (eds). 2004. The GLORIA Field Manual. Multi-Summit Approach. European Communities Commission. Directorate-General for Research. 89 pg.

SUMMARY & CONCLUSIONS

In summer 2004 we installed a standard multi-summit GLORIA target region (Pauli et al. 2004; code: SND) on four summits, ranging from treeline (3322 m) to alpine (3749 m) elevations in the central eastern Sierra Nevada, USA. Within these summit plots, we identified 65 plant taxa from 18 families. The lowest summit had an elevational transition flora, with the largest total number of species (38) and species unique to the summit (18). The treeline forest type that overlapped the lowest summit represented the most distinct community type of the four summits. Vegetation of the plots had two major biogeographic affinities: 1) shrubs, subshrubs and graminoids with a broad elevational and geographic range in montane and subalpine zone of the Sierra Nevada and Great Basin, and, 2) a truly alpine, cushion plant community. Potential upward migration of vegetation as a result of warming climates could cause local extirpation of the alpine zone, putting some restricted species at risk of loss of local habitat.