A Monitoring Program to Determine the Effect of Climate Change on Alpine Plant Communities in the San Juan Mountains: A New Site in the Global Observation Research Initiative in Alpine Environments (GLORIA) Program

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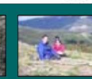
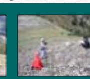
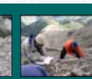
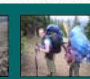





1) What is GLORIA and Why in the San Juan Mountains?

GLORIA is a long-term, global observation network for the comparative study of climate change impacts on mountain biodiversity, especially plants. There are more than 50 GLORIA target regions worldwide (Fig. 1).

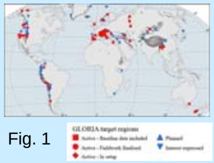
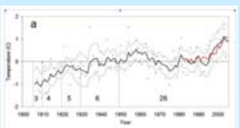


Fig. 1

Ecosystems of the alpine life zone are particularly sensitive to global warming because they are:

- Adapted to low temperature conditions.
- Limited to the extent that they can migrate to higher altitudes or latitudes due to the island nature of mountain tops.
- Contain relatively high number of endemic species (i.e., species that occur only locally) that are at risk of extinction.



A GLORIA site in the San Juan Mountains represents the southern extent of the U.S. Rocky Mountains. The San Juan Mountains have experienced pronounced warming over the past 15 years (Fig. 2). This project will enable us to understand how changing temperatures affect alpine tundra and treeline vegetation in this region.

Fig. 2. Anomalies in the mean annual surface air temperature from 1906-2005 in the San Juan Mountain region. (Data from HCN & SNOTEL. Analysis provided by Imtiaz Rangwala).

2) Methods

➢ Four summits along an altitudinal gradient from just above treeline to near the highest elevation in the region (Fig 3).

➢ Summit Criteria:

- Similar climate (except for altitudinal differences)
- Similar geology
- No or low-impact from land use or recreation.
- Relatively conical shape (no cliffs) so that all sides can be monitored.

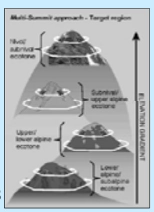


Fig. 3

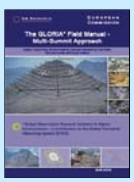


Fig. 4

➢ Plant species inventory for each summit, divided into 8 sections, down to 10 m vertical elevation below the highest point (Fig. 4).

➢ Detailed plant species coverage data for four quadrats per cardinal direction (16 per summit). Quadrats are arranged in the corners of 3 x 3 m^2 plots (Figs. 5 and 6).

➢ Four soil temperature data loggers per summit (one per cardinal direction buried in the center of each 3 x 3 m^2 plot, Fig. 5).

➢ Detailed measurements and photo documentation to allow plot re-location and re-survey in future years (Fig. 6).

➢ Statistical analyses of baseline data to explore patterns in species richness, diversity, and abundance (J. Crawford PhD dissertation).

Fig. 5.

3 x 3 m^2 plot containing 4x1m^2 quadrats (in corners of plot) and one soil temperature logger in center of plot.

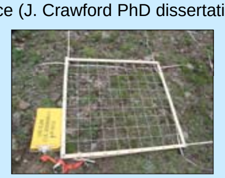
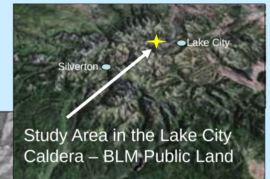
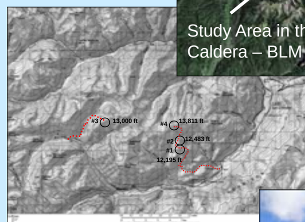


Fig. 6. One m^2 quadrat with frequency grid and label for photo documentation

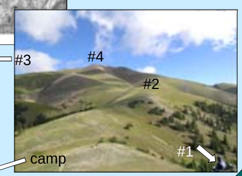
3) Location





Figs. 7, 8, 9 - Location of study area in the San Juan Mountains

Summit #1 (CSK) – 12,195 ft.
Summit #2 (ARR) – 12,483 ft.
Summit #3 (MCS) – 13,000 ft.
Summit #4 (PEP) – 13,811 ft.



4) Results

Species Richness & Diversity:

The SJM target area had slightly above-average species richness compared to the other GLORIA target areas globally. Ninety-seven (97) species were found in the SJM plots. This compares with a GLORIA mean of 92 and median of 79.

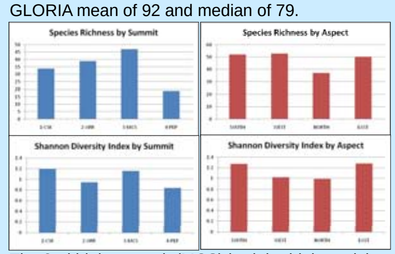


Fig. 10. Total richness and diversity for each summit (elevation) and aspect.

The 2nd highest peak (MCS) had the highest richness and diversity, but most species had very low or trace cover. Neither richness nor diversity was significantly different by summit or aspect, but the highest peak (PEP) and the N aspects tended to have the lowest richness and diversity.

		Species Richness	Species Diversity	Family Richness	Family Diversity
N=64	Aspect 1x1	0.049	0.171	0.265	0.35
	Elevation 1x1	< 0.001	< 0.001	< 0.001	< 0.001
N=16	Aspect 2x2	0.64	0.928	0.894	0.963
	Elevation 2x2	0.026	0.08	0.002	0.101
N=16	Aspect 5m	0.946	0.349	0.856	0.532
	Elevation 5m	0.073	0.049	0.014	0.031
N=16	Aspect 10m	0.906	0.965	0.845	1.00
	Elevation 10m	0.009	0.011	0.022	0.02

Elevation was a primary factor in relation to both species richness & diversity. Although the data suggest a trend, aspect is not a significant factor.

Fig. 11. Kruskal-Wallis permutation tests of 1x1 m^2, 2x2 m^2, 5 and 10 meter contour datasets.

4) Results Continued

Percent Cover:

The second highest peak (ARR) greatly surpassed the other peaks in overall vegetation cover. The lowest peak (CSK) had the second highest overall vegetation cover of the four peaks. Cover by aspect did not significantly differ.

Summit	Fern	Forb	Graminoid	Sellaginella	Total Cover	Relative Cover
PEP	0.00	14.05	6.54	0.50	21.09	5.27
MCS	0.01	20.83	11.38	0.21	32.43	8.11
ARR	0.00	66.91	136.00	23.00	225.91	56.48
CSK	0.00	41.03	23.67	9.75	74.45	18.61

Table 2. Percent cover of vegetation life form groups by peak.

Aspect	Fern	Forb	Graminoid	Sellaginella	Total Cover	Relative Cover
East	0.00	40.04	36.68	9.76	86.48	21.62
North	0.01	33.92	38.19	7.00	79.12	19.78
South	0.00	35.24	45.18	7.60	88.02	22.01
West	0.00	33.62	57.54	9.10	100.26	25.07

Table 3. Percent cover of vegetation life form groups by aspect.

Indicator species:

CSK	IV	p-value
Selaginella densa Rydb.	63	0.048
Mertensia lanceolata (Pursh) DC.	64	0.047
Poa glauca Vahl subsp. rupicola (Nash ex Rydb.) W.A. Weber	69	0.016
Trifolium nanum Torr.	75	0.003
Penstemon hallii Gray	88	0.01
Carex elynoides Holm.	91	0.004
Festuca brachyphylla Schult.	97	0.003
Potentilla ovina Macoun	98	0.005
ARR	**IV**	**p-value**
Astragalus alpinus L.	67	0.026
Townsendia leptotes (Gray) Osterhout	67	0.026
Poa lettermanii Vasey	82	0.052
Potentilla hippiana Lehm.	83	0.025
Artemisia scopulorum Gray	85	0.012
Artemisia campestris L.	92	0.009
Tetraneuris grandiflora (Torr. & Gray ex Gray) Parker	97	0.006
Oxytropis borealis DC. var. viscida (Nutt.) Welsh	100	0.002
Oxytropis parryi Gray	100	0.002
Potentilla concinna Richards.	100	0.002
MCS	**IV**	**p-value**
Trifolium nanum Torr.	19	0.003
PEP	**IV**	**p-value**
Carex albonigra Mack.	91	0.008
Carex nardina Fr.	90	0.009
Polemonium viscosum Nutt.	72	0.032
Trisetum spicatum (L.) K.Richt.	67	0.014

Table 4. Indicator species analysis (ISA) calculated an importance value and associated p-value for each species. Each peak had very unique indicator species, with one exception; *Trifolium nanum* was an indicator for both CSK and MCS.

Effect of Scale:

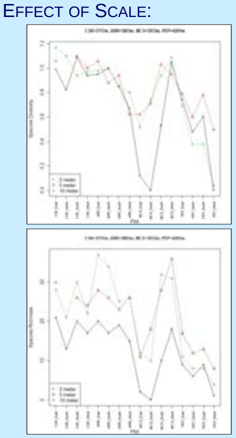


Fig. 11. Plots of species diversity and richness across 3 spatial scales. The 2x2 m^2 plots did not always capture the richness and diversity recorded in the much larger 5 or 10 meter summit areas. The small plots did capture similar patterns of richness and diversity as the larger areas, however.

THANKS TO: Peggy Lyon, Colorado Natural Heritage Program, for field botany help; John Wood, Professor Emeritus, NAU, for statistical help; and to Fort Lewis College and Truman State University students for field help.

FUNDED BY:

The Nature Conservancy
Mountain Studies Institute
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American Alpine Club
Colorado Mountain Club
Colorado Native Plant Society