

Fine-scale Phenology and Nitrogen-Fixing Microbes at a GLORIA Site in Southwestern Montana, USA

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Abstract

Global climate change is predicted to have a major impact on alpine environments and plants, including changes in the phenology of alpine plants in western North America. The GLORIA (Global Research Initiative in Alpine Environments) project is an international network of alpine sites for long-term monitoring of naturally-occurring alpine plants in the context of climate change. We established a GLORIA site in southwestern Montana in 2008 with four sub-summits of ascending elevation from treeline to the upper alpine with surveys of plants in quadrats at each cardinal direction and installed -20° to 50° C temperature loggers (Onset TB132). This GLORIA site is immediately east of the Continental Divide at Mt. Fleecer, (45°49'36.06"N, 112°48'08.18"W), a 2873 m (9425 ft.) peak situated between the Pintlar and Pioneer Mts., and at Mt. Keokirk, 2987.3 m, (9801 ft.), 45°35'37.94" N, 112°57'03.89" W, south of Mt. Fleecer in the Pioneer Mts. Phenology is an important aspect of life in the mountains. Herbaceous plants appear at different times throughout the growing season but can be virtually undetectable at other times. To determine when particular species can be detected, we constructed a time-series of photographs of plants at the 3m² and 1m² quadrats at the sub-summits at Mt. Fleecer in the summer of 2010, with the first set of photographs taken on July 9, just after snowmelt and the final set taken on August 28, just before snowfall. The photographs demonstrate that apparently new species are found when early and late season images are compared. Data on the timing intervals of vegetative growth, anthesis, fruiting, and seed dispersal as well as visualizations of the seasonal appearance and disappearance of the aboveground parts of different species can be extracted from the photographs in the time series. As a result of this study, several new species will be added to the Southwestern Montana GLORIA species list, including *Gentiana calycosa* and *Gentiana amarella*, which were in bloom at the treeline site in September 2010 but were not evident during the baseline survey in July 2008. Because nitrogen fixation is a critical process in alpine environments, the lives of alpine plants are intricately linked to those of nitrogen-fixing,

and often symbiotic, microbes. Therefore, it is not only the plants that may be affected by changes in climate but also the nitrogen-fixing microbes. To develop an understanding of the distribution of nitrogen-fixers, we initiated a survey of these microbes by searching for them in lichens, legumes, and cryptogamic crusts. Lichens from Mt. Fleecer contained photosynthetic green algae but did not contain nitrogen-fixing cyanobacteria. We have found root nodules with nitrogen-fixing bacteria in *Lupinus sp.* but not in *Oxytropis campestris*, another abundant legume from Mt. Fleecer. In addition, we are using microscopy to examine cryptogamic crusts of soils from meadows near the treeline and lower alpine sub-summits of Mt. Fleecer to determine whether nitrogen-fixing cyanobacteria are present and thus likely contributing nitrogen to the alpine ecosystem.

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