Global Change in the World's Mountains Conference, Perth, UK, September 28, 2010

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Factors affecting the current range limits of *Linaria dalmatica* in a mountainous area of the Northwest United States.

The movement of non-indigenous plant species into mountainous areas has become an increasingly discussed topic in the last decade. As such, many studies have been undertaken in an effort to understand the dynamics of non-indigenous plant species (NIS) invasions in mountain systems. Pauchard et al. (2009) highlighted several studies that have already documented a decrease in the number of NIS with increased elevation. Several reasons have been proposed as contributing to the trend of declining richness at higher elevations, including lower propagule supply (Aragon & Morales, 2003), less time since introduction (Becker et al., 2005), less disturbance (Kitayama & Muellerdombois, 1995), and less available land area (Korner, 2007). In an effort to understand and quantify what is driving this pattern, species level studies need to be conducted. We set up a study to evaluate if the decline in a particular NIS at high elevations is due to a lack of opportunity as suggested above, or if there are climatic factors limiting the ranges of individual NIS along an elevation gradients.

To determine the effects of elevation on the growth and reproductive output of the NIS *Linaria dalmatica* we established eighteen study sites along three mountain roads in the Absaroka-Beartooth Range (Montana, USA and Wyoming, USA) and the Northern Range of Yellowstone National Park (Wyoming USA) in 2008. The roads commenced at approximately 1700 m elevation and in all cases the upper elevation extents of the road were higher than the highest known *L. dalmatica* populations. Data on stem density, stem height, capsule and seed production, and seed germination were collected. Temperature loggers have been installed at each site since June 2009. Rain gauges and soil moisture sensors were installed in June 2010. The main goal of this ongoing study is to determine if the current range of *L. dalmatica* is influenced by climatic factors along the elevation gradients.

Available climate and *L. dalmatica* data were analyzed using linear regression or generalized linear models where appropriate. The elevation gradients in this study were characterized by linear increases in both early season (June-July) precipitation ($p<0.01$) and number of growing season (June-September) days with minimum temperatures at or below

freezing ($p<0.001$) with increased elevation. The mean minimum daily temperature declined with increasing elevation on both annual ($p<0.05$), and growing season scales ($p<0.01$). *L. dalmatica* displayed distinct patterns in stem density and reproductive characteristics along the elevation gradients. For 2008, a unimodal pattern was observed for overall stem density ($p<0.05$), flowering stem density ($p<0.001$), maximum stem height ($p<0.001$), seed capsule production ($p<0.001$), and estimated seed production ($p<0.001$) with all of these variables decreasing at either end of the elevation range. For seed collected during 2008, initial germination rates under standard conditions showed the same unimodal trend with increasing elevation ($p<0.001$). During 2009, only overall stem density showed the same trend as in 2008 ($p<0.01$). There was very weak evidence that flowering stems exhibited the same trend ($p = 0.09$). Stem height, seed capsule production, and estimated seed production showed no trend with increased elevation. Preliminary regression analysis of the 2009 data using available environmental predictor variables indicated that 55% of the variation in sexual reproductive output (seed production) of *L. dalmatica* was accounted for by percent bare ground, annual solar radiation, mean daily minimum temperature during the growing season, and early growing season precipitation. The study will continue for another two years but our preliminary analysis suggests that the range limits of *L. dalmatica* may be restricted by low precipitation at the lower end of the elevation gradients and by a combination of factors at the high end of the elevation gradients. The study also highlights that fine scale population dynamics and environmental data are necessary to better elucidate the processes driving invasion into mountain systems.

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