Evaluating effects of stress on orchid populations with integral projection models

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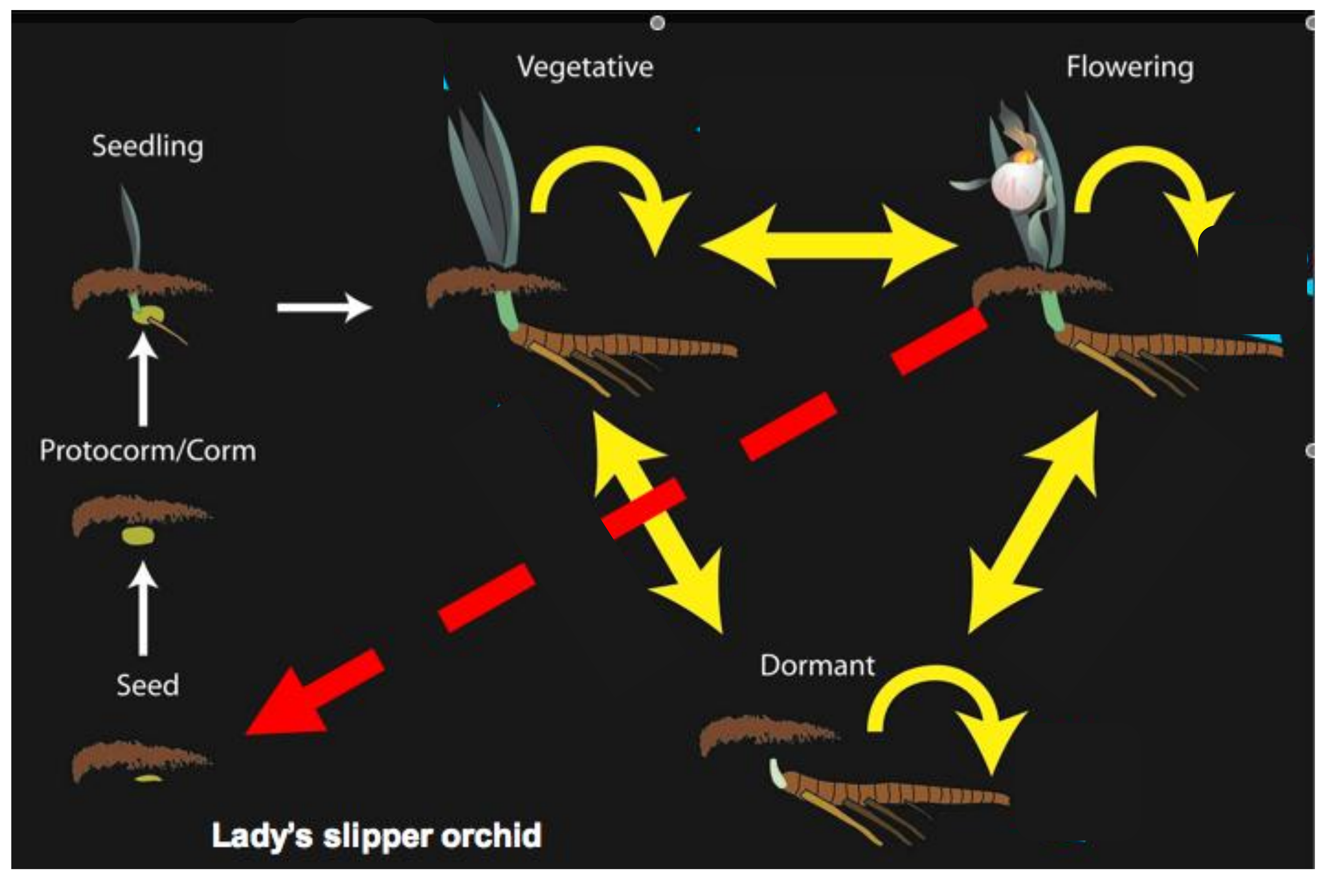
Abstract

Long-lived plants experience periods of acute stress during their lifetime that impact their demography and fitness. We induced stress (defoliation and heavy shading) on a natural population of the threatened lady-slipper orchid *Cypripedium calceolus*. We then utilized integral projection models (IPM's) to assess the effects of environmental stress on overall fitness (λ) via vital rates such as mortality and demographic transitions. Population growth of control plants was most sensitive to progression to and stasis at larger sizes. In treated plants, we found a greater importance to fitness of retrogression to and stasis of small plants and a cessation of reproduction. We emphasize the importance of demographic variability to survival and fitness of long-lived plant species.



Life history of *Cypripedium spp.*.

Introduction

Human impacts on the environment increase the frequency of stressful events that organisms face during their lifetimes. Understanding the effects of such events on fitness and the demographic parameters that affect it is integral to the conservation of rare species (Freville et al. 2004, Morris et al. 2008, Horvitz et al. 2010).

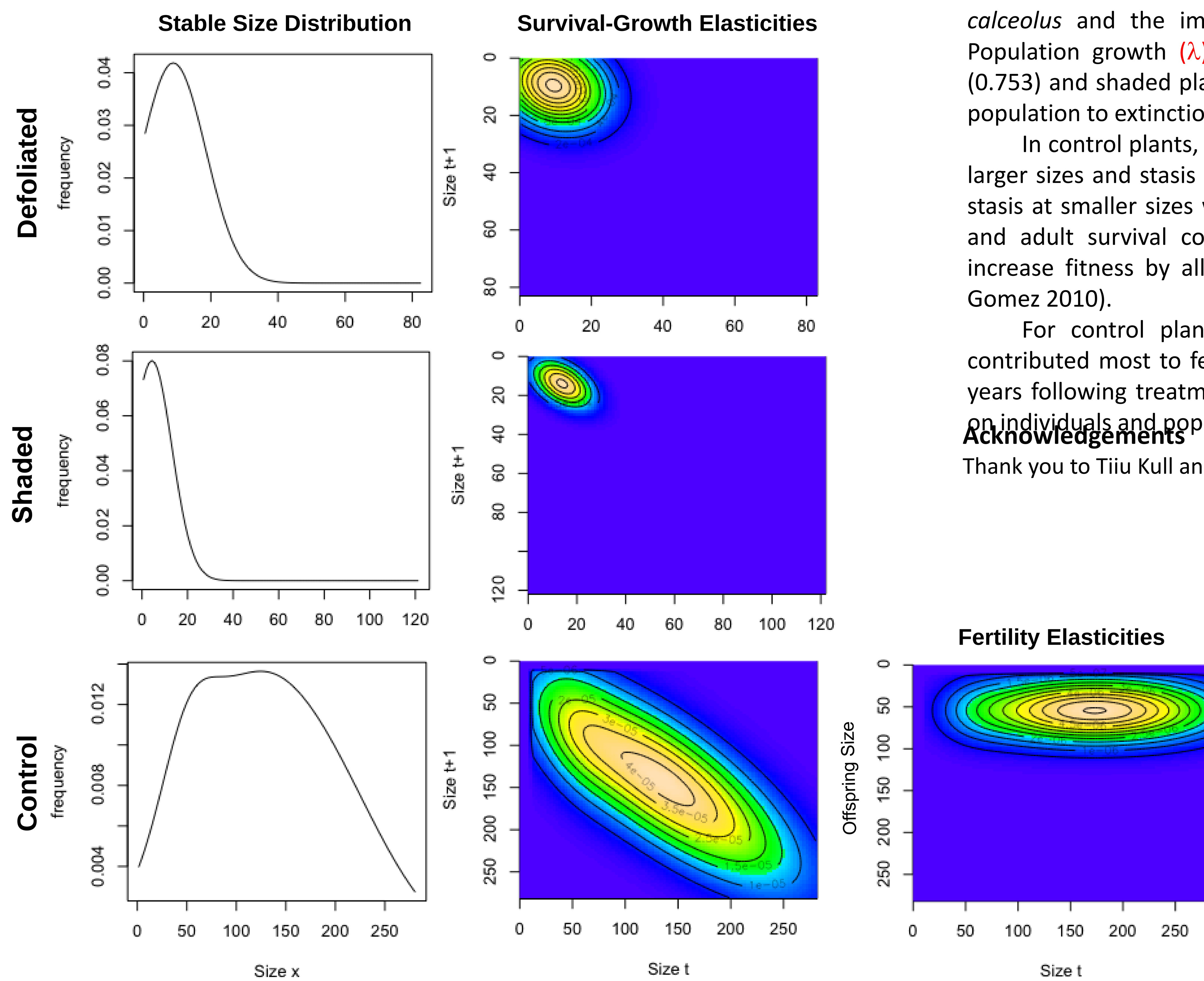
Many plant species live for numerous decades and undergo periods of growth, shrinkage, stasis, reproduction, and dormancy throughout their lives (Shefferson et al. 2005). Life history stages (sizes) and transitions that are important for population maintenance under normal conditions may be less important during periods of high stress, and vice versa. However, random stress events are unlikely to occur over the course of a standard demographic study. Experimental demography and demographic modeling allow us to manipulate the environment and assess the impact of high stress events without decades of demographic and environmental data. Integral projection models (IPM's) assess population growth and its sensitivity to life history parameters. IPM's are especially useful for species with small populations and complicated demography, such as orchids (Easterling and Ellner 2000, Ellner and Rees 2006).

Methods

Data used for this study are from a population of the yellow lady-slipper orchid, *Cypripedium calceolus,* on the island of Muhu in western Estonia.

To simulate periods of harsh environmental conditions, we designated some individuals for shading and some for defoliation (removal of aboveground growth) for the first two years of the study. Treatment was implemented as soon as sprouting occurred in 2002 and 2003, to prevent unhindered photosynthesis prior to treatment. For five years, we recorded the number and heights of ramets, and the number of leaves and flowers per ramet each year.

I constructed models of vital functions with census data from the Muhu population collected from 2002 to 2006 with SPSS, then used the vital rate functions to create three separate integral projection models for control, shaded, and defoliated plants following the framework established by Ellner and Rees (2006) in R (R Development Core Team, 2008).



Stable size distributions and elasticity plots for treatment and control plants.

Cypripedium calceolus population in Estonia

Results and Discussion

The results of this study highlight vulnerability of populations of *Cypripedium calceolus* and the importance of demographic variability during times of stress. Population growth (λ) for control plants was 1.01 and much lower for defoliated (0.753) and shaded plants (0.295). This indicates that a stressful year could drive this population to extinction.

In control plants, population growth is most sensitive to growth of small plants to larger sizes and stasis of plants over 150cm. For treated plants, retrogression to and stasis at smaller sizes was more important. *Cypripedium* individuals can be long-lived and adult survival contributes heavily to population growth, thus shrinkage may increase fitness by allowing individuals to survive through harsh periods (Saguero-Gomez 2010).

For control plants, flower production of plants of 150 to 200 cm of size contributed most to fecundity. Treated plants failed to produce flowers, even in the years following treatment, demonstrating that stress events have long lasting effects on individuals and populations.

Acknowledgements

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