Tree removal as a management strategy for the lady's slipper orchid

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Abstract – The lady's slipper orchid (*Cypripedium calceolus*) grows as an understory herb in boreal herb-rich forests, where the dominance of spruce often decreases light and nutrient availability. To study selective tree removal as a management method in northern Finland, we used long-term demographic data from ten unharvested control sites and ten harvest sites which were divided into three treatments with differing tree harvest intensity: (1) dense spruce forests, where half of the total tree basal area (TBA) was cut, (2) sparse spruce forests, where one-fourth of the spruce TBA was cut and (3) sparse broadleaf forests, where one-fourth of the total TBA was cut. Orchid flowering and fruiting probabilities were higher at the harvested spruce forests sites compared to control sites, while harvesting increased survival and ramet density at the moderately harvested broadleaf forest sites. The effects on flowering and fruiting probabilities and survival disappeared quickly, whereas ramet density responded only with a lag of several years. Tree removal had no effect on dormancy or seedling density. Our results demonstrate that for the lady's slipper orchid, a flagship species for nature conservation, the selective tree harvest might be a suitable management method that increases fruit production and the population size at the ramet level.

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INTRODUCTION

Understory light conditions and associated changes in e.g. temperature and moisture, are considered to be the major limiting components of forest understory cover and species richness in temperate and boreal forests (Barbier *et al.*, 2008). In addition to light, canopy closure affects many abiotic and biotic factors of the forest understory, which in turn can modify, both directly and indirectly, the growth, survival, and reproduction of understory plants (Figure. 1). In Finland, spruce-dominated old-growth forest represents a natural part of the succession cycle of herb-rich forests. *P. abies* offers shelter and substrate for certain birds and decomposing fungi (Alanen *et al.*, 1995), but also effectively shades the understory and produces acidic litter that decomposes slowly (Alanen *et al.*, 1995; Zhang *et al.*, 2008), and the subsequent resource limitation can be detrimental for herbaceous understory species.

The lady's slipper orchid (*Cypripedium calceolus* L.) is a rare understory herb which prefers half-shaded lime-rich habitats (Rankou and Bilz, 2014). Because of its large, showy flowers, the lady's slipper orchid is an ideal flagship species to attract public interest in conservation. Moreover, due to its stable population dynamics, occurrence on rare habitat types, and tendency to co-occur with several other rare orchids, herbs, and mosses, it has been suggested that the lady's slipper orchid could be used as an umbrella species (Bjørndalen, 2015; Laitinen, 2006; Nicolè *et al.*, 2005). In other words, the decline of the lady's slipper orchid indicates the degradation of the habitat, and therefore, an improvement in conditions for this orchid might ensure the survival of other species that are dependent on similar habitats (Simberloff, 1998).

Previous studies have shown that the viability of lady's slipper orchid populations decreases with increasing canopy closure in boreal and nemoral forests (Brzosko, 2002;

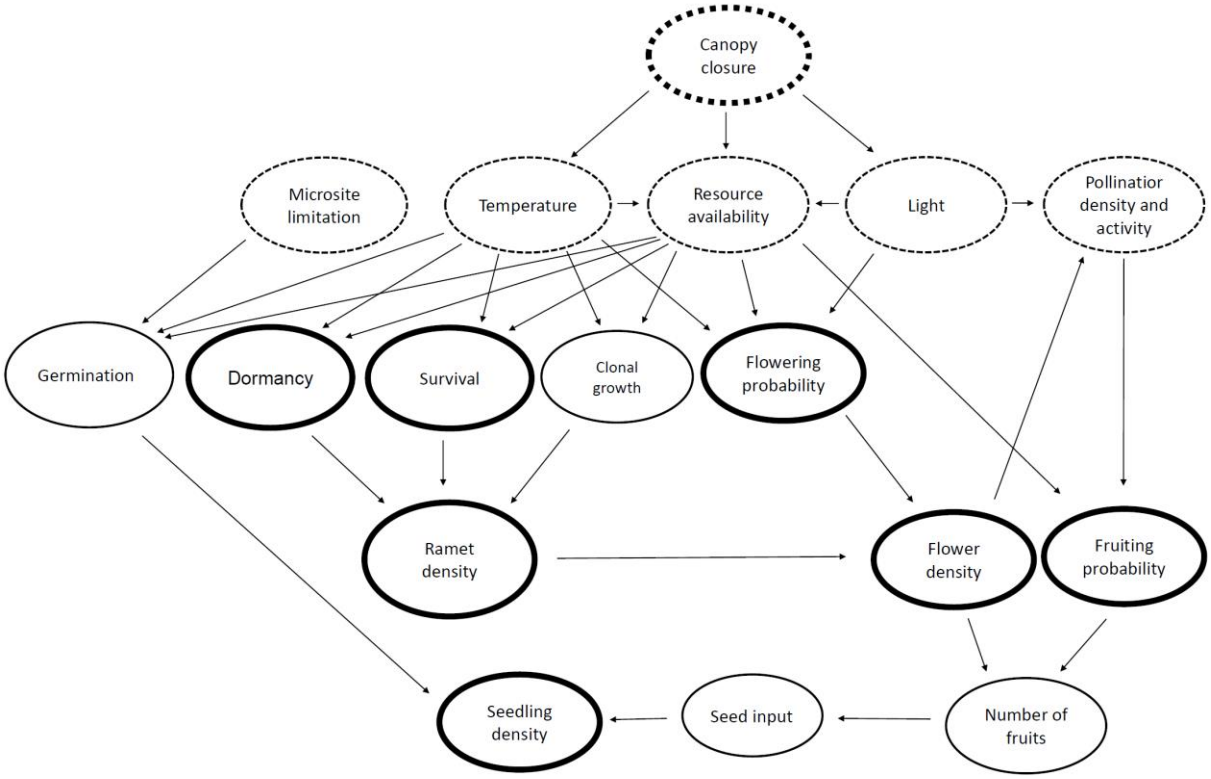

Figure 1. A flow-chart depicting the effects of canopy closure and abiotic factors (dashed line) on different demographic rates (solid lines) of forest understory herbs. Variables in bold circles are measured in the current study.

Kull, 1999; but see García *et al*., 2010) As noted in extensive field observations of this species, flowering probability, seed set, and seedling establishment are limited under closed-canopy conditions in boreal forests in northern Finland (Laitinen, 2006). Moreover, in a shading experiment, Shefferson *et al.* (2012) observed that the flower production and survival of shaded plants were lower than those of unshaded plants. These authors also noticed that orchids were able to escape the negative effects of shading through vegetative dormancy, a state in which a plant produces no above-ground shoots for one year or more, and only the below-ground rhizome survives (Shefferson *et al*., 2012).

In this study, we use long-term demographic data from northern Finland to examine whether selective tree harvest could be used as a management method for rare orchids in over-grown herb-rich forests.

METHODS

The lady's slipper orchid (*Cypripedium calceolus*) is a nectarless, clonal, long-lived herb with a horizontal rhizome. Ramets form clumps consisting of several clones, in which vegetative propagation dominates over sexual reproduction (Kull, 1995; Brzosko *et al.*, 2002). Some clones and ramets can remain dormant for several years, although one year is more typical (Brzosko, 2002; Shefferson *et al.*, 2001). One stalk supports one to two, rarely three, yellow slipper-shaped flowers. This orchid is mainly boreal, and is widely distributed from Europe to Asia. It has been declining in several countries, but many populations are now stable or increasing due to the implementation of successful conservation actions (Rankou and Bilz, 2014).

As part of the Metsähallitus' EU Life funded project in 2001 (details in Laitinen, 2006), ten lady's slipper orchid sites from northern Finland were chosen for active forest management and ten sites as controls. The habitats consisted of herb-rich forest. In the summer of 2001, a randomly located 1 × 10 m plot was established at each study site. At sites with under 100 ramets, an extra square (up to 8 m^2) was included to obtain a sufficient sample size. Each isolated ramet or ramet clump was marked using a steel stick with a numbered plastic label. We use a clump as a proxy for a

clone, as the ramets grow so closely together that we could not reliably follow them individually, and the identification of actual genetic clones would have required genetic tests or excavation of the plants.

In years 2001–2004, 2008–2010, and 2014–2016, we visited all sites once a year during the fruiting time in July and recorded the state of each ramet clump as dormant, vegetative, or flowering. The numbers of flowers and capsules were counted, and newly emerged clumps and seedlings were marked every year. Tree removal was conducted in the winter of 2001 (i.e. after the first summer survey). Three types of forest were represented in the management areas, and each differed in the intensity of selective tree harvest: (1) dense spruce forests, where half of the total tree basal area (TBA) was cut (mean of 48.9% (SD 8.4%)), (2) sparse spruce forests, where one-fourth of the spruce TBA was cut (mean reduction in TBA mean of 26.4% (SD 7.4%)), and (3) sparse broadleaf forests, where one-fourth of the total TBA was cut (mean reduction in TBA mean of 25.7% (SD 0.7%)). Control sites, in which no trees were cut, included the same forest types as the treated sites. The size of the managed areas varied from 600 m^2 to 1700 m^2, with the demography plot in the middle. Tree removal was conducted without heavy machinery and all logs and branches were removed from the sites. A thick snow cover protected the plants and ground from mechanical disturbance during cutting.

Clonal growth and sexual reproduction of the lady's slipper orchid were assessed using the following six variables: the densities of mature ramets and seedlings (per m^2), flowering probability, fruiting probability, dormancy and survival. We tested differences in demographic rates between managed and control sites using generalized linear mixed models, taking into account the starting level (the value of a given response variable in 2001 before treatment) and time period.

RESULTS AND DISCUSSION

A 25 – 50% reduction in tree basal area increased population size at the ramet-level by enhancing survival and clonal growth at sparse broadleaf forest sites, and increased the probabilities of flowering and fruiting at spruce forest sites, although these positive effects were not seen during all years (Figure.2). The positive effect of forest harvest on flowering and fruiting probabilities during the immediate post-harvest period was probably due to increased nutrient availability and increased pollinator density and activity (Figure 1) as the species is mostly pollinated by solitary bees of the genus *Andrena* that prefer open or half-open habitats (Antonelli *et al.*, 2009, Erneberg and Holm, 1999; Kull, 1999). However, the positive effects on

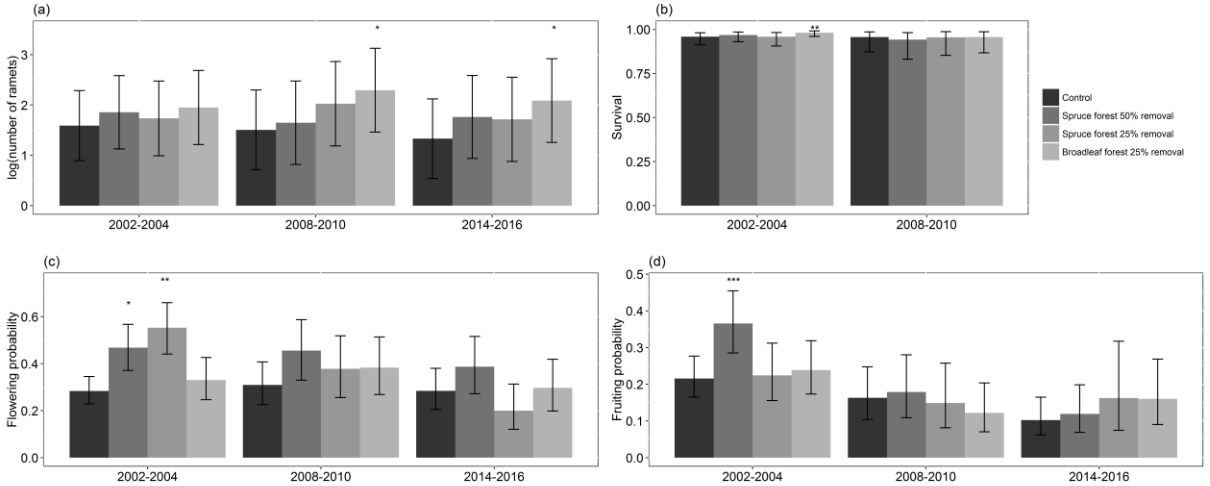

Figure 2. **(a)** Ramet density, **(b)** survival, **(c)** flowering probability, and **(d)** fruiting probability of the lady's slipper orchid by treatment and time period. Bar heights represent the model prediction, and error bars denote standard errors. Asterisks indicate a significant difference between the treatment and the control of the same time period. Predictions are averaged over geographic regions and starting level covariates. Count responses are on a logarithmic scale and proportional responses are back-transformed to the original proportion scale.

flowering and fruiting were seen only in the most intensive treatments and only during the first few years after tree removal. Furthermore, the increased capsule production did not translate into a significant increase in seedling production, suggesting that seedling production of the lady's slipper orchid is constrained by the number of favorable microsites rather than by the number of seeds (Kull, 1998). This calls into question the benefits of tree harvest for the sexual reproduction of this species.

However, tree removal appeared to increase the clonal reproduction and thus the population size at the ramet level, as the ramet density was significantly higher at the broadleaf 25% removal treatment sites than at the control sites (Figure 2.). Although this effect was seen with a lag of several years, it was persistent and still visible at the end of the study. This higher ramet density seems to be due to increased clonal growth (greater number of ramets per clone) and not, instead, the consequence of increased clump sprouting, as the treatments had no effects on the proportion of dormant clumps.

CONCLUSION

Previous observations from Scandinavia (Antonelli *et al.*, 2009; Bjørndalen, 2015) and our findings show that selective tree harvest might be a suitable management method for the lady's slipper orchid. Furthermore, while we can expect responses to change in canopy cover to be species- and habitat-specific, it is likely that tree removal could be used as a management method for other understory species whose reproduction benefits from canopy gaps.

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References

Alanen A., Leivo A., Lindgren L., Piri E. 1995. *Lehtojen hoito-opas* (Metsähallituksen luonnonsuojelujulkaisuja. Sarja B. No 26). Vantaa: Metsähallitus.

Antonelli A., Dahlberg C.J., Carlgren K.H.I., Appelqvist T. 2009. Pollination of the lady's slipper orchid (*Cypripedium calceolus*) in Scandinavia - taxonomic and conservational aspects. *Nord. J. Bot.*, 27: 266-273.

Barbier S., Gosselin F., Balandier P. 2008. Influence of tree species on understory vegetation diversity and mechanisms involved-A critical review for temperate and boreal forests. *Forest Ecol. Manage.*, 254: 1-15.

Bjørndalen J.E. 2015. Protection of Norwegian orchids – a review of achievements and challenges. *Eur. J. Environ. Sci.*, 121: 121-133.

Brzosko E. 2002. Dynamics of island populations of *Cypripedium calceolus* in the Biebrza river valley (north-east Poland). *Bot. J. Linn. Soc.*, 139: 67-77.

Erneberg M., Holm B. 1999. Bee size and pollen transfer in *Cypripedium calceolus*. *Nord. J. Bot.*, 19: 363-367.

García M.B., Goñi D., Guzmán D. 2010. Living at the edge: local versus positional factors in the long-term population dynamics of an endangered orchid. *Conserv. Biol.*, 24: 1219-1229.

Kull T. 1998. Fruit-set and recruitment in populations of *Cypripedium calceolus* L. in Estonia. *Bot. J. Linn. Soc.*, 126: 27-38.

Kull T. 1999. Biological flora of the British Isles. *Cypripedium calceolus* L. *J. Ecol.*, 87: 913-924.

Laitinen T. 2006. *Tikankontin tila Suomessa* [The conservation status of the Lady's slipper orchid (*Cypripedium calceolus* L.) in Finland]. Vantaa: Metsähallitus.

Nicolè F., Brzosko E., Till-Bottraud I. 2005. Population viability analysis of *Cypripedium calceolus* in a protected area: longevity, stability and persistence. *J. Ecol.*, 93: 716-726.

Rankou H., Bilz, M. 2014. *Cypripedium calceolus*. Retrieved April 19, 2017, from http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T162021A43316125.en.

Shefferson R.P., Kull T., Tali K., Kellett K.M. 2012. Linking vegetative dormancy to fitness in two long-lived herbaceous perennials. *Ecosphere*, 3: 1-19.

Shefferson R.P., Sandercock B.K., Proper J., Beissinger S.R. 2001. Estimating dormancy

and survival of a rare herbaceous perennial using mark-recapture models. *Ecology*, 82: 145-156.

Simberloff D. 1998. Flagships, umbrellas, and keystones: is single-species management passe in the landscape era? *Biol. Conserv.*, 83: 247-257.

Zhang D., Hui D., Luo Y., Zhou G. 2008. Rates of litter decomposition in terrestrial ecosystems: global patterns and controlling factors. *J. Plant Ecol.*, 1: 85-93