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Characterizing the Habitat and Life Stages of *Clintonia borealis* in High Elevation Forests

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Abstract

High elevation spruce-fir forests of the Southern Appalachians are facing threats from anthropogenic disturbances. One understory herb in this habitat is Bluebead Lily (*Clintonia borealis*), a clonal plant that occurs in scattered patches on the forest floor. My objective was to characterize the habitat of Bluebead Lily and document its life stages in the Black Mountains in western North Carolina. I searched for 40 patches of Bluebead Lily and recorded the number and size of plants in each patch, elevation, and species and diameter of the nearest overstory and understory trees. Results showed 45% of patches had at least one reproductive plant, but only 4.4% of plants were reproductive. Nearly half the plants had only 2 leaves, and < 5% had 4 leaves, which were the oldest plants and most likely to reproduce. Fraser Fir dominated both the overstory and understory of surveyed patches, and it is likely that the decline in Fraser Fir due to the invasive balsam woolly adelgid will negatively impact Bluebead Lily in this habitat.

Introduction

The spruce-fir forests of the Southern Appalachians are rich in rare and endemic species (Smith et al., 1998). As glacial relictual from the Pleistocene, these forest communities occur in limited areas, and growing conditions are characterized by high elevations, frequent rainfall, and cool temperatures (Stehn et al., 2010). The dominant tree species are Fraser Fir (*Abies fraseri*) and Red Spruce (*Picea rubens*) (Radford et al., 1968). Both species are facing threats from direct and indirect anthropogenic disturbances, which limit their vigor and abundance and are leading to rapid and unknown ecosystem changes (McManamay et al., 2011).

Among the most recent and harmful disturbances was the accidental introduction of the exotic balsam woolly adelgid (*Adelges piceae*). This insect feeds predominantly in bark fissures of Fraser Fir trees > 4 cm in diameter. As it feeds, it injects salivary compounds that cause the host tree to reduce sapwood conductance, contributing to decreased water and nutrient delivery (Eager, 1984). This results in severe water stress in the host tree, leading to mortality within 2-7 years (Eager, 1984). The decline of Fraser Fir is having an impact on the ecosystem as a whole, due to increases in the amount of sunlight and wind reaching the forest floor (USDA Forest Service, n.d.).

One forest understory herb that occurs in the spruce-fir forest is Bluebead Lily (*Clintonia borealis*), a clonal plant that propagates predominantly through underground rhizomes and occurs in dense and distinct patches (Pitelka et al., 1985). In its mature reproductive stage, it produces bright blue fruits, although seedling recruitment is rare (Eriksson, 1992). Our objective was to characterize the habitat of Bluebead Lily and document its life stages in high-elevation forests in the Black Mountains. Since the decline of Fraser fir is threatening the ecological integrity of southern Appalachian spruce-fir forests, our investigation will help us better understand how these changes might impact this herbaceous species.

Methods

Our study was conducted in the Black Mountains in Western North Carolina, in the vicinity of Mount Mitchell. Patches of *Clintonia borealis* were studied at three sites between July and August 2023: Deep Gap Trail, Mountains to Sea Trail at the summit of Mt. Mitchell, and Mountains to Sea Trail at Blackstock Knob. We surveyed 40 patches; all patches were ≥ 6 m away from trails, to minimize disturbance from foot traffic. Patches were defined as discrete clusters of ramets that were spatially separated from other clusters, and were widely scattered across the forest floor. We encountered 10 patches near the summit of Mount Mitchell, 21 patches on the Deep Gap Trail, and 9 patches on Blackstock Knob.

In each patch, the number of leaves and reproductive status (flowering or fruiting stems) of all plants in the patch were noted. We also measured elevation, and identified the nearest overstory and understory trees. We recorded the presence of moss, lichen, and herbaceous plants within the patch, along with the species and number of tree seedlings.

Results

We documented an average of 38 plants per patch (Table 1). Out of all the patches, 45% had reproductive stems present but there was only a mean of 1.2

reproductive plants per patch. There was a mean of 5 tree seedlings within a patch with the majority composed of Fraser fir. Nearly half of Bluebead Lily plants had only 2 leaves, and < 5% had 4 leaves, which were the oldest plants and most likely to reproduce (Fig. 1). Nearly every reproductive plant had 4 leaves; there were a few with 3 leaves.

Table 1. Summary of Patch Data: Bluebead Lily Population, Reproductive Status, and Patch Characteristics

No. of patches surveyed	40
Mean no. plants per patch	38.3
Patches with repro. stems (%)	45.0
Mean no. repro. plants per patch	1.2
Mean no. of tree seedlings per patch	5.5

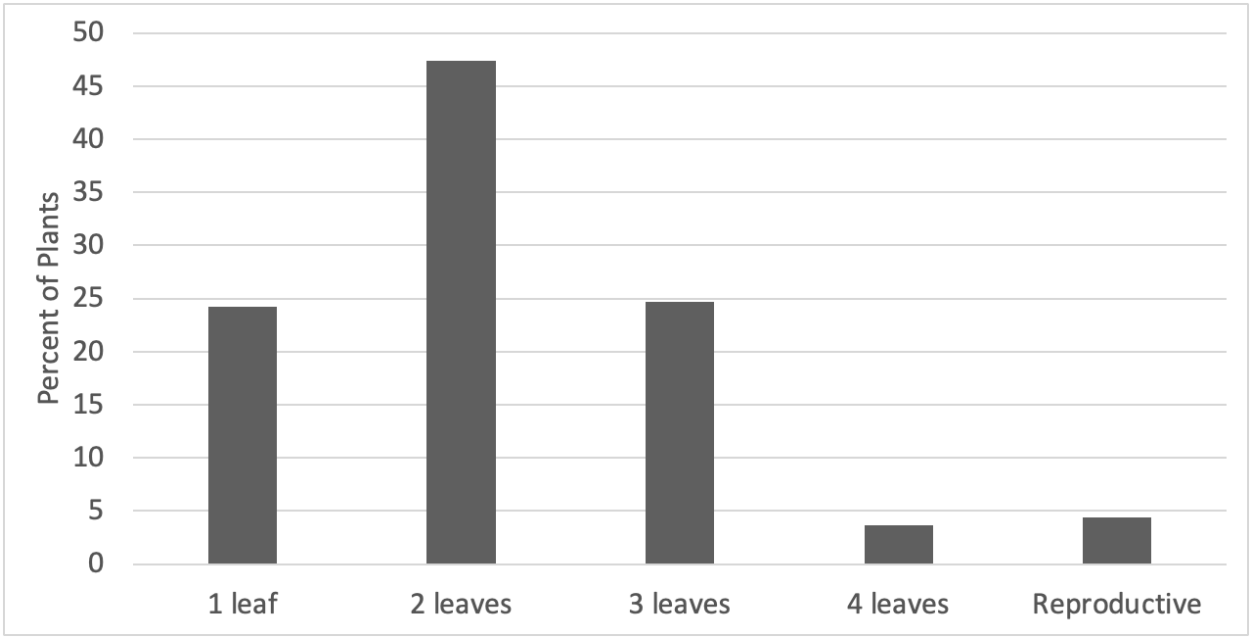

Figure 1. Growth Stage and Reproductive Status of Bluebead Lily Plants Surveyed

We surveyed patches between 1,700 - 2,000 m, with the mean elevation being 1,923 m. There was a steep decline in the occurrence of Bluebead Lily patches in deciduous forests at elevations < 1,660 m, so we did not survey below this threshold. The dominant overstory and understory tree species was Fraser fir, which made up 70% of the overstory and 47.5% of the understory (Table 2). Nearly all patches had co-occurring mosses and forest herbs (Table 3).

Table 2. Overstory and Understory Tree Species Distribution in Relation to Bluebead Lily Patches

Tree Species	Overstory (%)	Understory (%)
Fraser fir	70.0	47.5
Red spruce	20.0	15.0
Yellow Birch	7.5	5.0
Mountain Ash	2.5	25.0
Mountain Maple	-	2.5
Rhododendron	-	2.5

Table 3: Ground-layer Vegetation Present in 40 Patches of Bluebead Lily

Types of vegetation	Percent of Patches	Standard Error
Tree seedlings	80.0	0.063
Moss	90.0	0.047
Herbs	82.5	0.060

Discussion

Bluebead Lily (Clintonia borealis) primarily propagates through underground rhizomes and rarely through seedling recruitment (Pitelka et al., 1985). In their study, Pitelka and colleagues found no evidence of new genets establishing within the surveyed patches over the five years preceding their research. They concluded that even in large patches, population growth is likely to result from the dominance of one or two original genets. We found very little reproduction in terms of flowering and fruiting. Most plants we encountered had two leaves, none of which we observed to be reproductive. The establishment of new patches is infrequent, and established patches persist for long periods of time (Eriksson, 1992). If patches die or decline as a result of the loss of Fraser fir, it could be hard for this plant to recover, making it especially vulnerable to the changes occurring in the spruce-fir forests.

Our findings reveal a strong relationship between Bluebead Lily and Fraser fir, 70% of the closest overstory trees and 47.5% of the closest understory trees to our patches were Fraser fir. The decline of Fraser fir due to the balsam woolly adelgid infestation is concerning because this tree has a large impact on the structure and function of high-elevation Southern Appalachian ecosystems (Chowdhury, MacDonald, & Jenkins, 2017). Gaps in the overstory occur when Fraser firs die, resulting in higher light levels on the forest floor, along with higher temperatures and drier soils. This can affect the microclimate for other species associated with this habitat (Martínez & López, 2005). Fraser fir provides favorable growing conditions for Bluebead Lily to thrive (North Carolina Cooperative Extension, n.d.). Bluebead Lily does best in shaded sites with moist, and acidic soils. In dense stands of Fraser fir, soils are usually highly acidic, with a pH around 3.6 (USDA Forest Service, n.d.). The increased light on the forest floor associated with the loss of Fraser fir from the overstory could increase competition from tree seedlings and other forest herbs, which could overtake slow-growing Bluebead Lily.

We observed little herbivory on Bluebead Lily, with no mammalian or insect feeding noted. We did observe several instances of snails feeding on leaves. It has

been documented that Bluebead Lily's nectar and pollen are a source of food for bees, flies, and beetles, and that chipmunks and some bird species eat the berries (North Carolina Cooperative Extension, n.d.). It is unlikely though, that any decline in Bluebead Lily would have much impact on fauna in spruce-fir forests.

Conclusion

The anthropogenic disturbances threatening the ecological integrity of high-elevation spruce-fir forests are causing rapid changes within the ecosystem, such as a decline in the proportion of Fraser fir. Given the close relationship between Bluebead Lily and Fraser fir, this could also result in a decline in Bluebead Lily at high elevations. Bluebead Lily does not typically propagate through seedling recruitment, so if patches decline, it might be hard to recover, making it a potentially vulnerable species.

Our study showed that most plants had 2 leaves, and only a few had four leaves, which we observed to be the most likely growth stage to flower and fruit. Fraser fir trees made up 70% of the nearest overstory trees and 48% of the nearest understory trees. Based on this information, it is reasonable to assume that the Bluebead Lily will undergo changes due to the loss of the Fraser fir, driven by both direct and indirect anthropogenic disturbances.

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