Variation in bird foraging behavior and abundance between hemlock forested sites treated and untreated for hemlock woolly adelgid

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Introduction

Hemlock woolly adelgid (*Adelges tsugae,* hereafter: HWA) is an invasive insect that feeds on Eastern hemlock (*Tsuga canadensis*). Since its introduction to the country, it has spread across the eastern U.S., causing widespread, high mortality in hemlock populations. Hemlock provides important ecosystem services, including habitat for many birds[1]. Decreasing abundance of bird species strongly associated with hemlock, especially the Acadian flycatcher and blue-headed vireo, has been well-documented in heavily-infested areas[2]. However, other aspects of bird ecology, such as foraging behavior, have not been examined in relation to HWA. In addition, no studies have focused on how avian communities may be affected by chemical treatments for HWA. Imidacloprid, a pesticide that is applied to the soil around the tree or into the trunk, is currently the most common form of controlling HWA[1]. In this study, we examined the foraging behavior of two hemlock associates, Acadian flycatcher (*Empidonax virescens,* ACFL) and blue-headed vireo (*Vireo solitarius,* BHVI), between treated and untreated hemlock stands. We expected to see higher foraging rates at treated sites, where hemlocks would be healthier and therefore providing better foraging habitat.

Field Sites

Data were collected in hemlock forests in eastern Kentucky at or near sites of a previous study[3]. Some sites had been treated with imidacloprid.

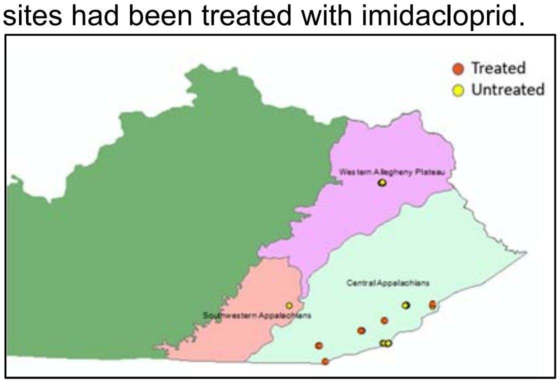

Figure 1. *Points indicate treated and untreated field sites in eastern Kentucky. Colored and labeled areas of the state indicate Appalachian ecoregions.*

Methods

Bird observations – Observers followed each bird for as long as possible using a voice recorder to note all searching maneuvers (hop, short flight, long flight) and foraging behaviors (glean, sally strike, sally hover)[4].
Vegetation survey – A 10-factor wedge prism was used to identify which trees to include in the survey. For each tree that was “in”, the species and estimated DBH was recorded. DBH was classified into 10 cm categories (1-10 cm, 10-20 cm, and so on). All hemlocks were assessed for overall health on a 1-5 scale (1 being healthy, 5 being dead) and whether they had been chemically treated.
Bird abundance – We analyzed the changes in Acadian flycatcher and blue-headed vireo abundance using point count data from 65 hemlock sites surveyed in 2009 and 2018[3]. Point counts were done in 2009. All sites were assumed to be untreated and minimally affected by HWA in 2009.
Analysis – Foraging rates were compared between treated and untreated sites using unequal variances t-tests. A 2-factor ANOVA was used to compare abundances between 2009 and 2018 and between treated and untreated sites.

Results

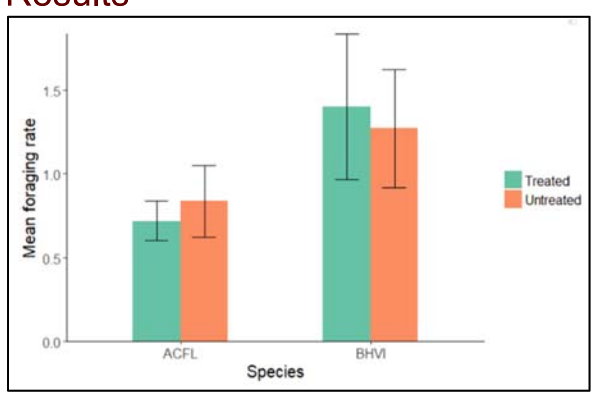

Figure 2. *Mean (± SE) foraging rate of Acadian flycatchers and blue-headed vireos between chemically treated and untreated hemlock sites.*

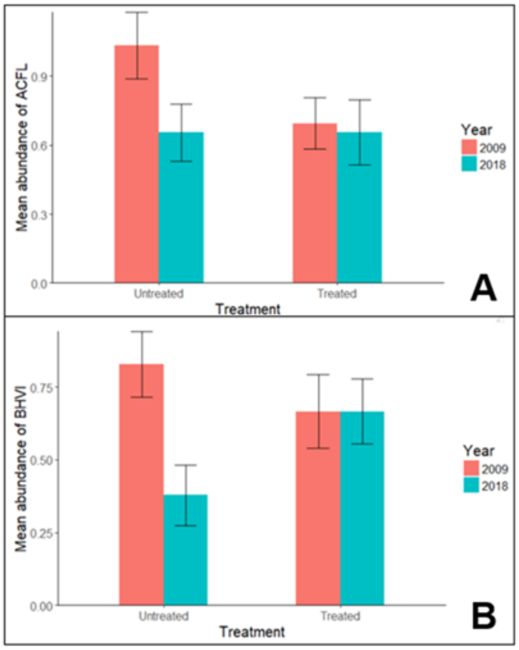

Figure 3. *Mean (± SE) Acadian flycatcher (**A**) and blue-headed vireo abundance (**B**) in chemically treated and untreated sites in 2009 and 2018.*

There was no significant difference in bird foraging rates between treated and untreated hemlock sites for both the Acadian flycatcher ($t_{15.97} = -0.47$, $p = 0.64$, **Figure 2**) and blue-headed vireo ($t_{15.96} = 0.23$, $p = 0.82$, **Figure 2**). For Acadian flycatcher abundance there was no significant interaction between treatment and year ($F_{1,125} = 1.69$, $p = 0.82$, **Figure 3A**), while blue-headed vireo abundance showed a marginally significant interaction between treatment and year, following the expected pattern of decreased abundance between 2009 and 2018 at untreated sites and unchanged abundance at treated sites ($F_{1,126} = 3.70$, $p = 0.057$, **Figure 3B**). Mean vireo abundance dropped from 0.83 to 0.38 at untreated sites, while mean abundance at treated sites stayed the same ($\bar{x} = 0.67$, **Figure 3B**).

Discussion

Both species did not forage at significantly different rates between treated and untreated hemlock sites, suggesting that chemical treatment for HWA did not impact their foraging behavior. Potential reasons for this may include that we were not able to detect differences in foraging behavior with our methodology. It is also possible that HWA is affecting another aspect of their ecology, such as creating less suitable habitat for nesting. Flycatchers show a strong preference for nesting in hemlocks, so increased defoliation from HWA infestation may be causing birds to avoid nesting in heavily-infested areas[5]. In addition, comparing insect abundance between treated and untreated sites may be a more effective way of studying the impacts of HWA treatment on bird species. In previous literature, mean insect species abundance was found to be lower in treated areas[6], which suggests that foraging would be more difficult for birds in treated sites. Conversely, the insects that birds prey on may be unaffected or benefited by treatments. Future research should explore prey availability in relation to HWA treatment.

These results, although not statistically significant, suggest that chemical treatment over time influences the abundance of these hemlock associates. This trend of decreasing abundance in untreated sites may become more pronounced in the future as hemlock health continues to decline in untreated areas. We conclude that continued treatment of hemlock trees is important for maintaining suitable habitat for these hemlock associates.

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