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DYNAMICS OF WILD RED RASPBERRY (RUBUS IDAEUS L.) AND THE INFLUENCE ON TREE REGENERATION WITHIN SILVICULTURAL OPENINGS IN A NORTHERN HARDWOOD STAND

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By

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Abstract

Previous studies have investigated how the abundance of raspberries (*Rubus idaeus* L.) impacts tree regeneration, but few have linked these impacts to location within canopy openings with a legacy tree. To fill this knowledge gap, we investigated the presence, abundance, and location of raspberries within openings containing legacy trees and the resulting impacts on tree regeneration. During the winter of 2003, 49 openings were created of three sizes: small, medium, large and 20 reference single-tree selection sites in a northern hardwood stand in Ford Forest near Alberta, Michigan. Tree regeneration and vegetative species cover were recorded in 2005 and were re-sampled in 2016. Results show raspberries not only persisted, but increased throughout the time-period. In addition, raspberry abundance varied by location within the openings. Furthermore, high abundance of raspberries was shown to decrease total tree seedling count. However, high abundance of raspberry did not hinder the growth of saplings within treatment areas. These results provide silviculturists beneficial information when deciding if raspberry control is necessary.

1 Introduction

Among the many herbaceous and shrub species that grow in northern hardwood sites, wild red raspberry (*Rubus idaeus* L.) commonly forms a dense cover across open sites following disturbances in the upper Great Lakes region (Whitney 1986; Lautenschlager 1997). This dense vegetative cover may compete with the regeneration of tree species. Therefore, understanding the dynamics of raspberries following silvicultural treatments may be beneficial to forest management decisions.

Raspberries have a short lifespan, rapid height growth, shallow rooting depth, and low root to shoot ratio. This translates into rapid above ground cover and early seed production after disturbance opens a site (Grime 1979; Donoso and Nyland 2006). Furthermore, the organic layer of a site may contain large amounts of buried raspberry seeds. For example, some variations of *R. idaeus* such as *R. idaeus* var. *strigosis*, can produce >26,000 seeds/m^2 over a 4-year period (Oleskevich *et al.* 1996). In addition, *R. idaeus* species can reach over 2 m in height, potentially creating competition for other vegetative species (Oleskevich *et al.* 1996).

Raspberries have been found to have a significant uptake of nutrients in a forest system. Hornbeck *et al*. (1987) found that between 2 and 10-years post silvicultural treatment, raspberry played a key role in nutrient uptake in the treatment units. However, as raspberry stem density declined through time, the death of the raspberries released nutrients making nutrients available for tree regeneration. This may release seedlings by increasing the amount of available light and nutrients.

Removing 40% or more of the canopy creates conditions ideal for the extensive establishment of raspberry (Donoso and Nyland 2006). Shields and Webster (2007) found two years after gap opening in a northern hardwood stand, raspberry was more common among gap sites than in sites with closed canopy. These results provide evidence that dense canopies are unfavorable to raspberries which supports hypotheses relating to disturbed sites commonly being suitable for raspberry establishment.

Raspberries have been found in some cases to have a negative impact on seedling establishment and growth. For example, Prévost and Charlette (2015) found that raspberry persisted in 30-m diameter gap cuts 10-years post-treatment and provided evidence showing raspberry competition constrained yellow birch (*Betula alleghaniensis* L.) seedling response to gap size in a northern hardwood forest. Gauthier *et al*. (2016) found that in a northern hardwood forest, yellow birch density decreased with increasing cover of raspberries. Persistence of raspberry decreased with time as described by Archambault *et al.* (1988) found when coverage of raspberry (0.5–1.0 m tall) covered 60% of the site 5 years post-clearcut and decreased to 2% after 20 years in a balsam fir (*Abies balsamea* (L.) Mill.)- yellow birch ecosystem.

In contrast, studies have also shown that raspberry cover may in fact benefit tree establishment and growth. In a yellow and black birch (*Betula alleghaniensis* Britt., and *Betula lalento* L.) and pin cherry (*Prunus pensylvanica* L.) stand in Pennsylvania, as raspberry cover increased the grass and fern cover declined. This evidence creates the argument that raspberries may in fact help promote the establishment of longer-lived tree species (Horsley and Marquis 1983). In addition, microclimates of silvicultural treatments such as clear-cuts can be hot and dry, with frequent extreme lethal maximum temperatures of 107 °F after clearcutting, as observed within northern hardwoods in New Brunswick (Roberts and Dong 1993). When raspberries are present, the resulting shade is thought to reduce temperatures and aid in keeping soils cool and moist. Other research has found that herbs and shrubs such as raspberries, protect tree seedlings from browsing animals (Waldstad and Kuch 1987). This cover is thought to provide seedlings with enough time to become established and possibly allow for an increase in height significant enough for their terminal bud to be out of reach of herbivores.

These results suggest that *R. ideaus* can have positive and negative influences on the success of tree regeneration, depending on site factors. This suggests that further studies are needed to fully understand the impact of *R. ideaus* on tree regeneration, and provide forest managers with better guidance to improve regeneration success in a range of silvicultural systems. Therefore, the objectives of this study are to analyze persistence, abundance and location of raspberry through time and to measure the impacts of raspberries on tree establishment and growth within the treatment areas.

2 Methods

Study site

The study site is located in an uneven-aged northern hardwood forest within the western upper peninsula of Michigan (Section 30, T49N, R33W, 46°s7’N, 88°29’W). Keys *et al*. (1995) describe this area as part of the Laurentian mixed forest. The terrain consists of even to hilly till plains, moraines, depressions and waterways which consist of moderately well-drained cobbly silt loams in upland areas and poorly drained silt muck in low areas (Berndt 1988). The average temperature ranged from -10°C in January to 18°C in July between 1981 to 2010 (NOAA 2010a). Average precipitation from 1981 to 2010 was 84 cm of rain and 381 cm of snow per year (NOAA 2010).

Bourdo and Johnson (1957) (as reviewed by Neuendorff *et al*., 2007) described the forest as pine-hardwood but due to harvest of white pine (*Pinus strobis* L.) between 1870 and 1890 little pine remains. After the donation of the land to Michigan Technological University (MTU), by Ford Motor Company in 1954, the forest has been managed using single-tree selection. These silvicultural practices through time have led to the increased dominance of shade-tolerant species such as maple (Neuendorff *et al.* 2007).

The study area is composed primarily of sugar maple (*Acer saccharum* Marshall) and red maple (*Acer rubrum* L.), with interspersed groups of eastern hemlock (*Tsuga Canadensis* (L.) Carriere) and varying amounts of yellow birch. Species less common throughout site include American elm (*Ulmus americana* L.), black cherry (*Prunus serotina* Ehrh.), red oak (*Quercus rubra* L.), American basswood (*Tilia americana* L.), eastern white pine (*Pinus strobus* L.), balsam fir, northern white cedar (*Thuja occidentalis* L.), and white birch (*Betula papyrifera* Marshall).

Experimental design

This research utilizes data from a long-term study investigating the ecological response and regeneration of yellow birch, to harvested openings surrounding a legacy yellow birch intended to serve as a seed source (Shields and Webster 2007). During the winter of 2003, 49 of these openings were created with an initial canopy openings of three sizes: 1) small with a radius of 0.5 x mean canopy height in which all rooted stems >10 cm diameter at breast height (DBH) were cut (267± 62 m^2, mean ± 1 standard deviation, n=16), 2) medium with a radius of 0.75 x canopy height (642 ± 85 m^2, n=17), and 3) large with a radius of 1.0 x canopy height (1192 ± 155 m^2, n=17). Canopy height of forest was 22 m. The forest matrix between the harvested openings was managed using single-tree selection. Twenty randomly selected yellow birch in this forest matrix were selected to use as reference sites.

Data collection

During the summer of 2005, plots were established along transects in the cardinal and sub-cardinal azimuths within each group-selection opening (Shields and Webster 2007). Each plot consisted of a 3.14 m^2 circular plot with a nested 1 m^2 square quadrat (Figure 1.) For each cardinal transect, one plot was randomly placed between the stem and the crown edge of the yellow birch seed tree and one between the edge of the birch crown and the edge of the group-selection opening. Plots under the yellow birch crown were at least 1 m from the crown edge (Figure 1). This sampling protocol provided 8 plots per site (49 openings and 20 reference plots; 552 regeneration plots in total). Plots were also established around the twenty yellow birch trees selected to use as reference sites, using the same plot design as the openings.

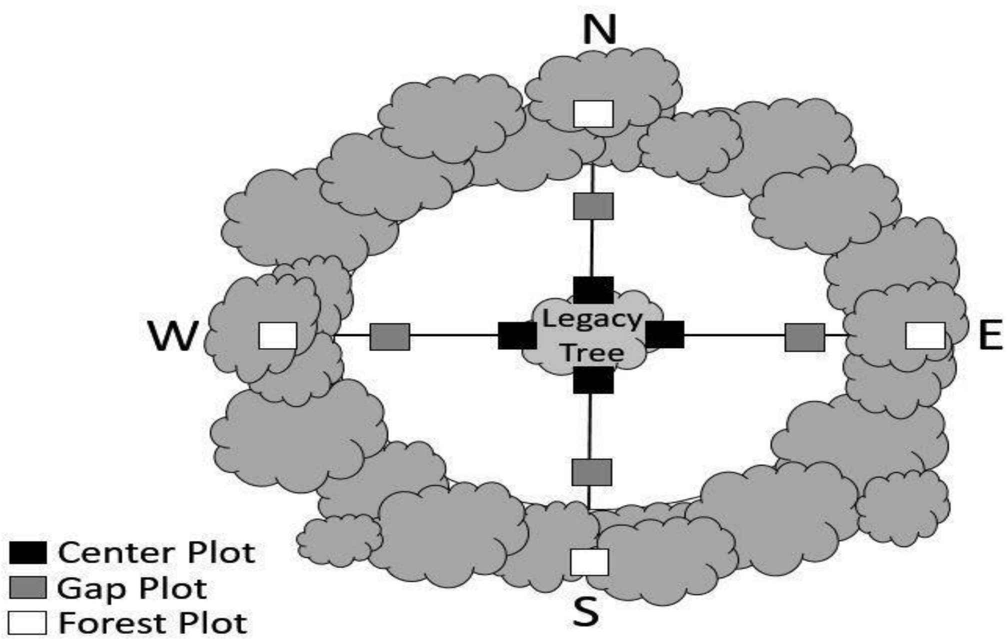

Figure 1. Layout of transects and plot within treatment areas. Note, forest plots were surveyed in 2016 only.

Within each 3.14 m² circular plot, the height of all saplings was measured (≥ 50 cm tall, but < 10 cm DBH). Seedlings (< 50 cm tall) were counted by species. Within the 1 m^2 nested quadrat, percent covers of tree seedlings, woody shrubs, forbs (including herbaceous vines), graminoids, ferns and fern allies, mosses, and lichens were visually estimated. Percent cover of bare soil, rocks, and woody debris was also recorded. Percent cover estimates were performed by a single observer to reduce observer bias.

During the summer of 2016, methods from 2005 were repeated. In addition, additional plots were established between 1 and 30 m from forest edge into the forest. Due to time constraints and only 43 of the original 49 openings were re-measured. This sampling protocol provided 12 regeneration plots per site (43 openings and 20 reference plots; 756 regeneration plots in total).

Statistical analysis

To determine which variables influenced raspberry cover presence through time, raspberry cover data was converted to binary factor presence/absence data for both 2005 and 2016 and binomial logistic regression methods were applied. Because forest plots were measured in 2016 only, only plots in the center and gap could be included in this analysis (497 plots). These converted data were used to test raspberry presence in 2016 as a function of raspberry presence in 2005, opening size (single-tree selection, small, medium, large), transect direction (north, south, east, west) and location of plot within transect (center and gap) ($n = 497$, $\alpha=0.05$).

To determine the impact of raspberry cover on tree regeneration, we converted raspberry cover the 756 plots in 2016, to the midpoint percent (0%,1%, 3%, 8%, 18%, 38%, 63%, and 98%) cover of the raspberry species data. We tested the data for normality, linearity, and equal variance, but none of these assumptions were met even after transformation of the data. This precluded our use of linear regression and other common parametric analyses for this particular analysis. These data were then analyzed using a negative binomial regression due to the large amount of 0% cover ratings. We analyzed seedling counts from all 756 plots measured in 2016 as a function of raspberry cover, opening size (single-tree selection, small, medium, large), transect direction (north, south, east, west), and location of plot within transect (center, gap, and forest) ($n = 756$, $\alpha=0.05$).

Lastly, we investigated the long term impacts of raspberry abundance on tree regeneration. To do this, we analyzed seedling mean height and max height in the 497 plots in 2016 as a function of raspberry abundance in 2005, opening size (single-tree selection, small, medium, large), transect direction (north, south, east, west), and location of plot within transect (center and gap) using a general linear model ($n = 497$, $\alpha=0.05$).

All analyses were conducted in R statistical analysis program (R Core Team 2015).

3 Results

Presence and persistence of raspberry

The abundance of plots with raspberry increased from 2005 to 2016 (Figure 2). The presence of raspberry in a plot in 2005 was a statistically significant predictor of the presence of raspberry in 2016, suggesting that raspberry persisted within a plot from 2005 to 2016 ($P < 0.001$). Mean raspberry cover within plots increased in the medium and large openings, but declined in the small opening and single-tree selection treatments (Figure 3). Raspberry abundance also became more variable within plots between 2005 and 2016, as indicated by the diverse raspberry cover means and standard errors across all opening sizes and plot locations in 2016 (Figure 4). In 2016, the presence of raspberry did not vary significantly among the transect azimuths ($P > 0.05$); however, there was a difference between the center and gap plot locations, showing the presence of raspberry was 2.7 times more likely in the gap locations ($P < 0.001$). In addition, raspberry presence was found to be significantly different between the small and large sized openings ($P = 0.02$) and medium and small sized openings ($P = 0.03$). However, there was no difference between medium and large sized openings ($P > 0.05$).

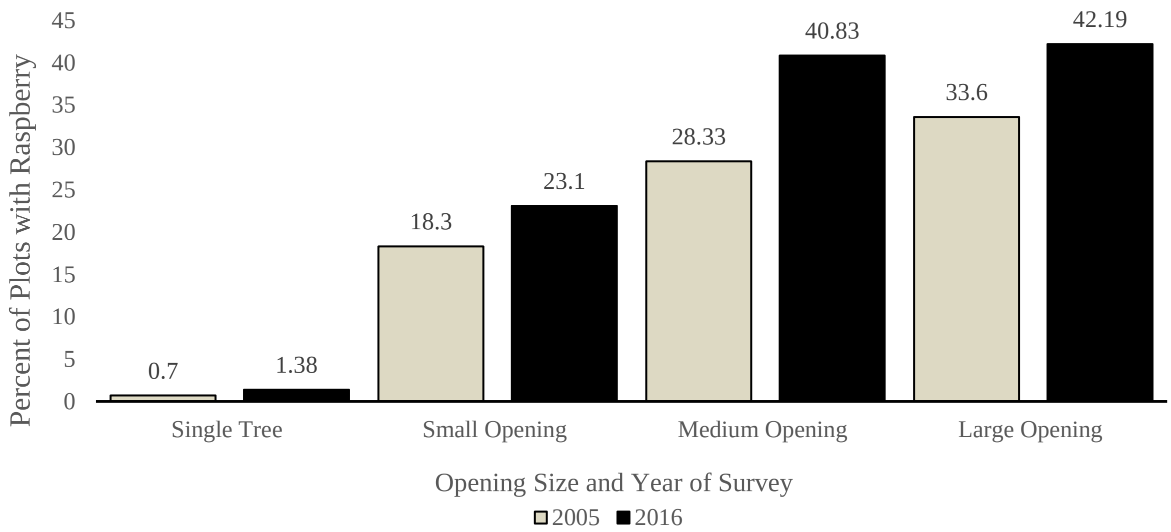

Figure 2. Percent of plots with raspberry (*Rubus idaeus*) present in 2005 and 2016 in group-selection openings at the Ford Forestry Center, Alberta, MI.

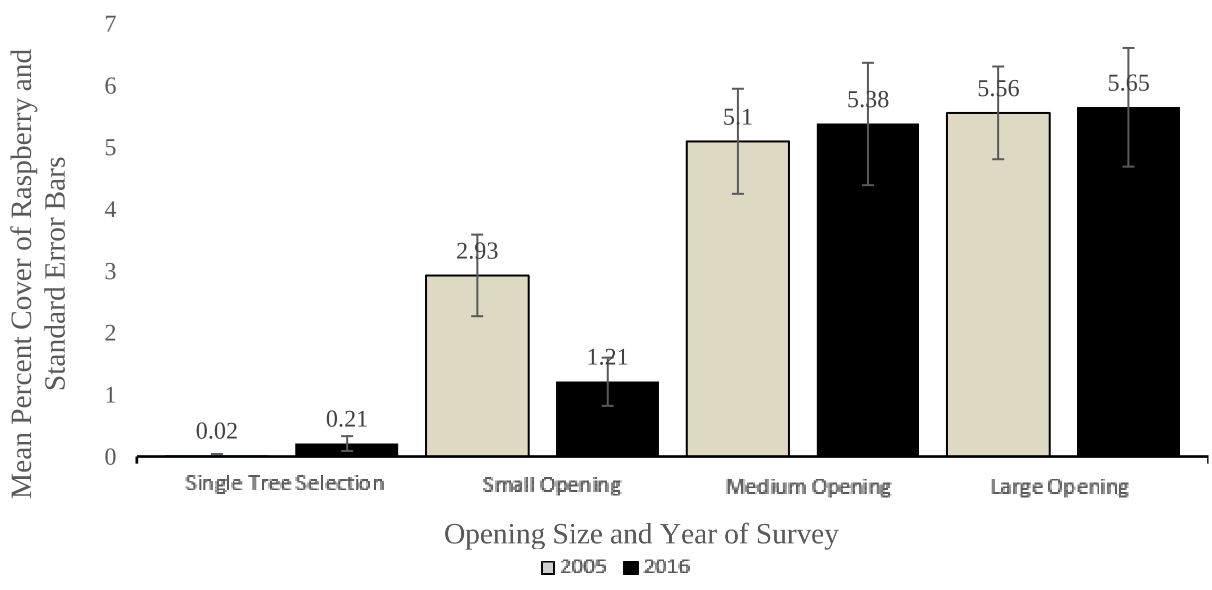

Figure 3. Mean percent cover of raspberry (*Rubus idaeus*) by opening size class and in single-tree selection reference plots at the Ford Forestry Center, Alberta, MI.

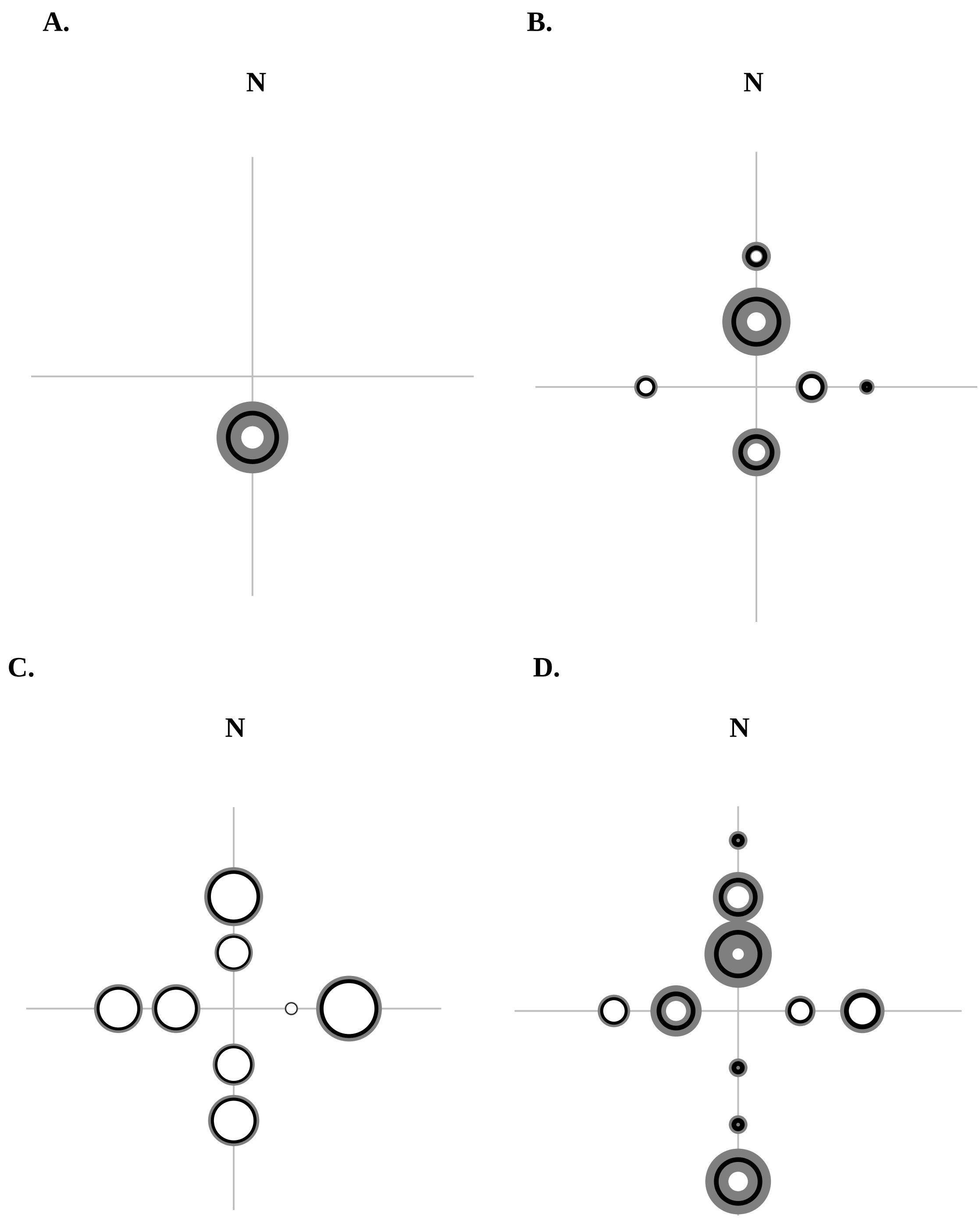

Figure 4. Mean raspberry cover (unfilled black circles) +/- 1 standard error (gray shading) at each plot location along the transects for forested controls (A. and B.), small (C. and D.), medium (E. and F.) and large openings (G. And H.) in 2005 (A, C, E, G) and 2016 (B, D, F, H). Note, that forest plots were measured in 2016 but not in 2005.

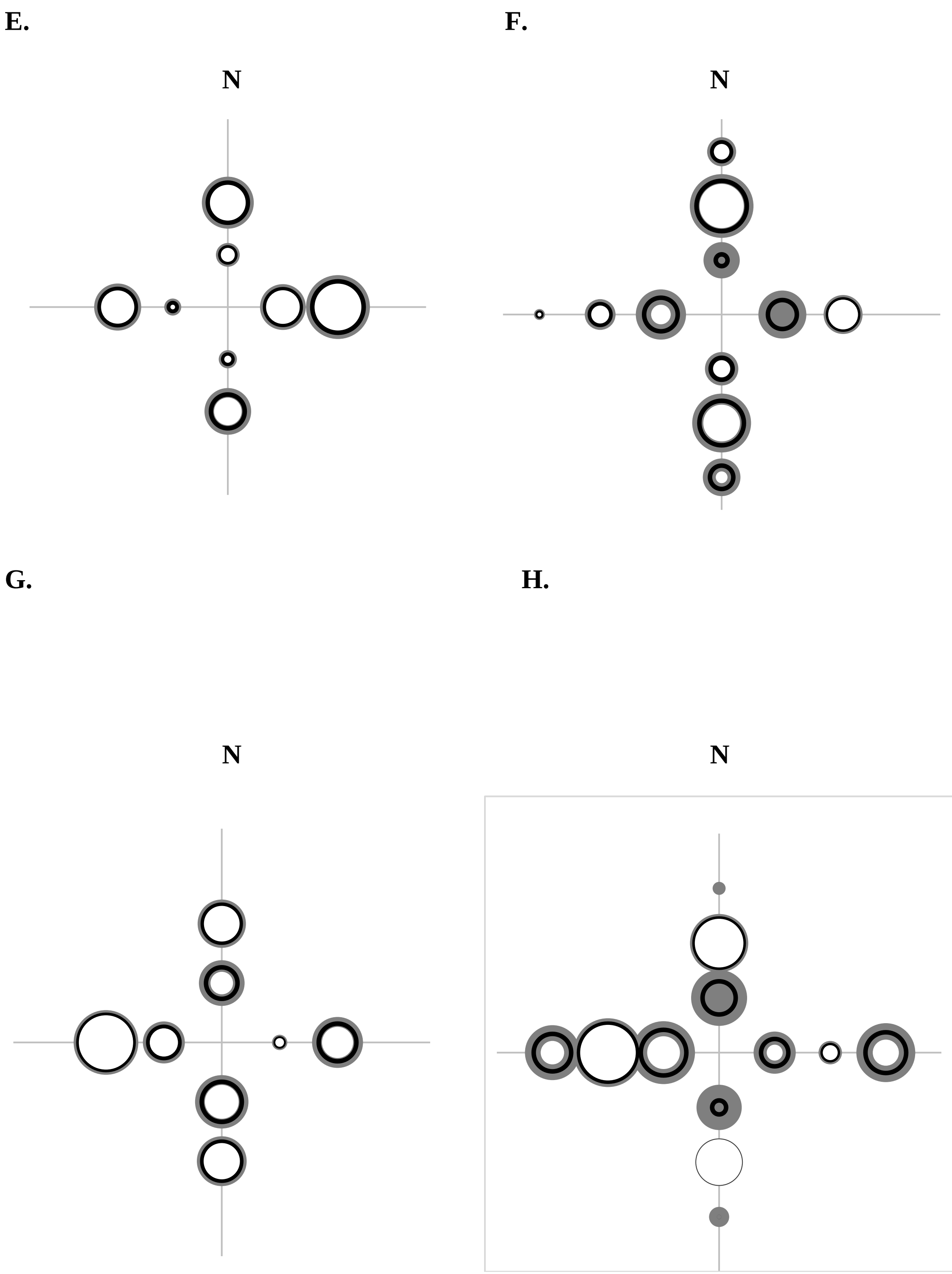

Figure 4. Continued

Raspberry abundance and influence on regeneration

Increased raspberry abundance negatively associated with total seedling count in 2016 ($P = 0.02$; Figure 5). However, raspberry abundance showed no associations with seedling count, opening size, transect direction, or plot location within transect. ($P > 0.05$). Furthermore, raspberry abundance did not have an impact on sapling maximum height or mean height ($P > 0.05$).

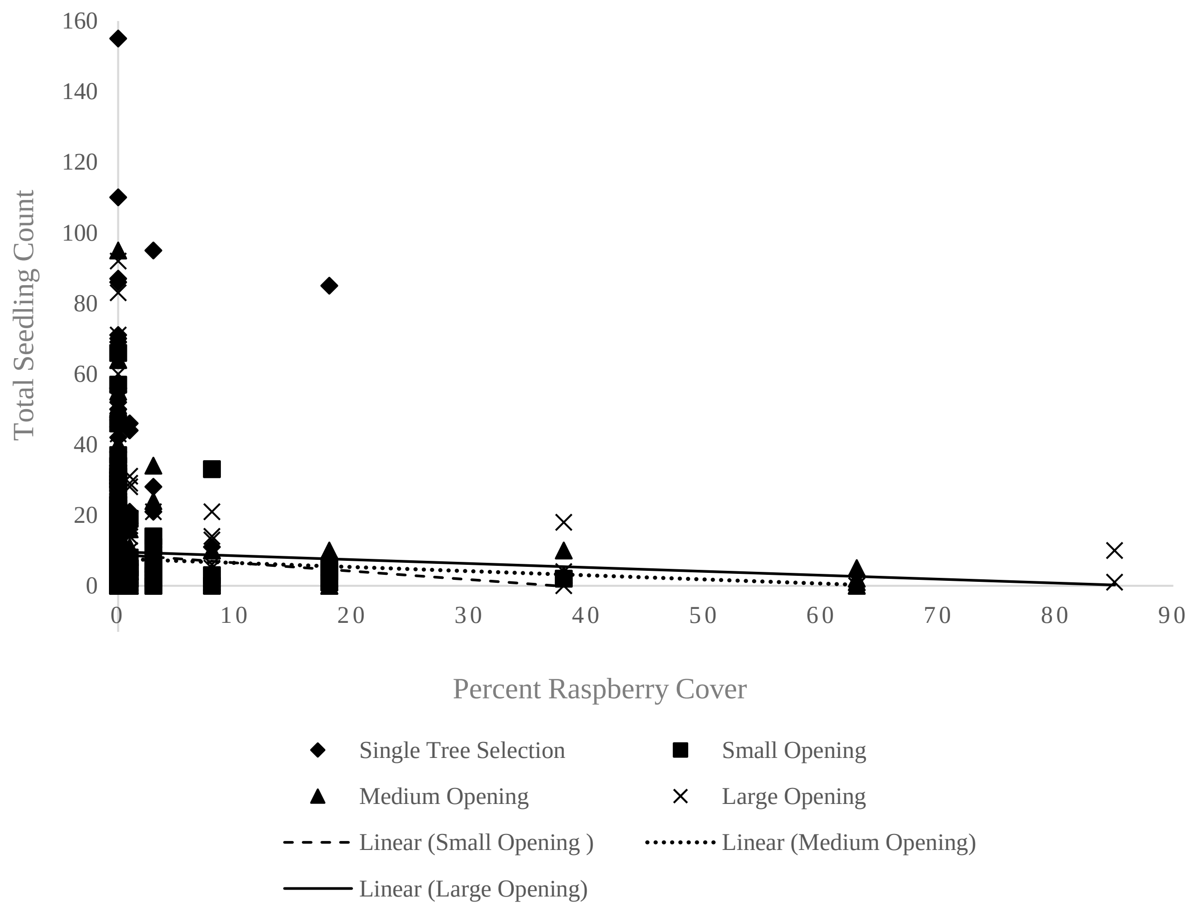

Figure 5. Mean percent cover of raspberry and total seedling count in 2016. Note, trend line not shown for single-tree selection data due to lack of plots with raspberry presence.

4 Discussion

Persistence and abundance of raspberry

We have found that raspberries did persist within treatment areas throughout the 11-year period. In addition, raspberries were shown to have a negative impact on the establishment and or survival of seedlings. However, no impact was observed on the height of the seedlings that did survive. This may indicate that raspberries over the long term may not decrease time in which it takes for a forest to regenerate.

Results are consistent with Whitney (1986), and Lautenschlager (1997), in which raspberries are more likely to form dense cover within disturbed areas as opposed to undisturbed. This is an important because forest harvest is a disturbance and understanding plant dynamics post-harvest is vital to management considerations.

Our results are similar to Prévost and Charlette (2015) and also show that raspberry can persist for 11-years post-disturbance. We cannot verify whether the same raspberry plant persisted or if there has been turnover of individual raspberry plants growing within each plot. Regardless, the species persisted. Raspberries are thought to create competition for other plant species and potentially alter growing conditions. With these considerations, the long-term establishment of raspberries may have an impact on the establishment of some tree species, making this a potential consideration for management.

Influence of location within opening on raspberry persistence and abundance

Transect azimuth was not found to be significant predictor of raspberry location within an opening. I hypothesized that the shadows cast by the legacy yellow birch may reduce raspberry abundance within the north transects, but this was not shown in the results. In addition, it was thought that the southern transect may have less raspberry due to the shade cast by the forest, but again this was not the case. Consequently, while raspberries may require a substantial amount of sunlight, full exposure may not be required.

In contrast to transect direction, location of plot along transect was found to be significant showing that raspberry is more likely to be present within plots in the gap location compared to the center plots. The difference in the presence of raspberry between these transect locations was statistically significant. This indicates that raspberries do not require but benefit from full exposure to the sun. When plots are in close proximity to the legacy yellow birch, it may cast enough shade to reduce raspberry abundance but not eliminate it entirely. In addition, considering the high temperatures within openings, the center plot location may have been more suitable for tree regeneration due to the shade created by the legacy yellow birch decreasing temperatures and increasing soil moisture. This increased regeneration may cause competition for raspberry, thus reducing plots with raspberry presence.

Raspberry abundance was also shown to have become more variable through the time analyzed (Figure 4.). This may indicate that raspberries abundance may fluctuate within a single area long term. Specifically, if raspberries densely cover an area at one point in time, it does not mean there will still be dense raspberry cover in that location in the future. This makes predicting the location of high raspberry abundance difficult.

Raspberry abundance and influence on regeneration

Our results show that there is a decrease in tree seedling count when there is increased abundance of raspberry, which agrees with the results of Gauthier *et* al. (2016), where high abundance of raspberry decreased yellow birch density. This may indicate that raspberries provide enough competition to reduce the successful establishment seedlings.

Unexpectedly, there was not a decrease in seedling maximum height or mean height in 2016 plots which had high raspberry abundance in 2005. This indicates that even though high abundance of raspberries reduces seedling count, they may not hinder the growth of the seedlings that are established. However, this could also mean that if shade tolerant trees such as maple, which was the dominant species of regeneration, were growing under the shade of raspberry, it may not hinder the growth of these species because they are adapted to this environment. If this were true, raspberry cover may create favorable environments for shade tolerant species, thus reducing habitat for shade intolerant species.

6 Conclusion

Overall, forest succession requires time and a major concern of high raspberry abundance is how much time it could add to the regeneration of tree species. This study has shown that raspberries did persist and increase in abundance through the 11-year period, and even decrease the count of seedlings within treatment areas. However, no indication of a decrease in sapling maximum or mean height was found, suggesting raspberries may not have a significant effect on forest regeneration in the long-term. Therefore, evidence supporting the control of raspberry is not shown by our research.

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