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Urban ragweed populations in vacant lots: An ecological perspective on management

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ABSTRACT

Ragweed (*Ambrosia artemisiifolia* L.) is one of the most prolific producers of allergenic pollen in North America, and negatively impacts tens of millions of people each year. Recent work shows that local plant populations can be the most important source of allergenic pollen in the urban environment. This research emphasizes that management choices that influence species abundance can determine the burden of allergenic pollen for people living near these plant populations. In Detroit, MI, USA, ragweed populations are predominantly found in vacant lots; the management of these lots could therefore have large impacts on allergenic pollen burdens. The main form of management in these vacant lots is mowing, which occurs at frequencies ranging from monthly mowing to no mowing. We hypothesized that annual or biennial mowing would result in conditions where ragweed populations could thrive. To test this, we conducted a vegetation survey of vacant lots in Detroit, in which we quantified the mowing regime, characteristics of the vegetation, and ragweed presence and stem density. We found that ragweed was significantly more likely to be present in lots that were mowed annually or biennially; unfortunately these are the most common management types, accounting for 51% of vacant lots in Detroit. Ragweed's association with this disturbance regime fits with its early successional status, as it is most competitive in recently disturbed soils where there is reduced competition for resources such as light. We therefore recommend one of two alternative management regimes for reducing ragweed in vacant lots: either mow them frequently (multiple times a growing season) or do not mow them at all. Both approaches will reduce ragweed prevalence in vacant lots and reduce allergenic pollen exposure for people who live near vacant lots.

Introduction

Plants in urban areas provide many important ecosystem services (Bolund and Hunhammar, 1999; Robinson and Lundholm, 2012), but some species negatively impact human health (e.g., Mohan et al., 2006; D'Amato et al., 2007). Common ragweed (*Ambrosia artemisiifolia* L., hereafter referred to as ragweed) is the epitome of an ecosystem disservice provider because of its prodigious production of allergenic pollen. Individual plants can produce up to 10^8 or 10^9 grains of pollen annually (e.g., Rogers et al., 2006; Fumanal et al., 2007; Simard and Benoit, 2011), yet as few as 10 grains/m^3 are enough to spark allergic rhinitis (Solomon, 1984). Although allergic rhinitis is sometimes thought of as merely a nuisance, it has serious health and social consequences: it dramatically increases medication costs and causes the loss of more than 2 million school days and 3.5 million workdays annually in the United States (Nathan, 2007). Economic costs of ragweed on a per capita basis have been estimated at €225 annually per susceptible person; this scales up to a cost of more than €290 million annually when extended to a national scale for Austria and Germany (Richter et al., 2013). Ragweed allergies are even more prevelent in the United States, where over 20% of the population is sensitized to ragweed pollen (Quest Diagnostics Health Trends, 2011). Moreover, ragweed pollen peaks have been linked to higher rates of hospital visits (Breton et al., 2006), and there is some evidence that allergenic pollen can trigger asthma attacks (Huynh et al., 2010). The importance of ragweed will also become increasingly important over the coming decades; as climates warm and carbon dioxide concentrations increase, ragweed will produce more allergenic pollen in the areas where it already exists (Ziska et al., 2003, 2011; Singer et al., 2005) and expand its range poleward (Chapman et al., 2013).

Although ragweed pollen can be transported hundreds of kilometers (D'Amato et al., 2007; Zink et al., 2012), a recent study shows

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that in urban environments airborne ragweed pollen concentrations are strongly correlated with ragweed population abundance at spatial scales ranging from 10 m to 1 km (Katz and Carey, 2014). The importance of local vegetation to airborne pollen concentrations is also corroborated by Skjøth et al. (2013) and Bricchi et al. (2000). Our growing understanding of short-range pollen dispersal indicates that ragweed management within a metropolitan area could be an effective way to reduce the burden of allergenic pollen.

Within urban areas, ragweed is common in vacant lots (e.g., Falck, 2010; Vincent and Bergeron, 1985). In fact, vacant lots in Detroit contain densities of ragweed that are six times higher than occupied residences (1.2 and 0.2 plants/m^2 respectively; Katz and Carey, 2014). Vacant lots are a common land use in many cities, and it has been estimated that as much as 15.4% of total land area in US cities is vacant or unused (Pagano and Bowman, 2000); in some neighborhoods of Detroit it is over 50% (Detroit Residential Parcel Survey, 2009). Because vacant lots are the main source of ragweed pollen production in Detroit, vacant lot management is virtually synonymous with ragweed management.

The main management regime for vacant lots in Detroit is mowing; this is also the most common management technique used for ragweed control in many cities (Simard and Benoit, 2011), although other forms of chemical and mechanical control can be used (Buttenschøn et al., 2010). A large body of literature shows that while mowing does in fact reduce the biomass of individual ragweed stems, and the amount of pollen produced by mowed plants in that year (Vincent and Ahmim, 1985), it must be done multiple times a year to be effective (Bohren et al., 2008; Simard and Benoit, 2011) and this still does not prevent flowering (Buttenschøn et al., 2010; Patracchini et al., 2011). Moreover, most studies on this subject have been conducted in controlled experimental conditions, and few look at the long-term impacts of mowing on ragweed.

Thus, despite the effort invested in finding the best way to manage individual ragweed plants with mowing, there is no empirical evidence that occasional mowing reduces ragweed populations; indeed, browsing and mowing promote the dominance of a closely related species of ragweed (Vermeire and Gillen, 2000; Vermeire et al., 2005). Ecological theory also casts serious doubt on the efficacy of mowing to control ragweed plants. Specifically, because ragweed is an early successional species (Vincent and Bergeron, 1985), the very efforts to control ragweed may create the disturbed conditions in which ragweed thrives: few perennial plants with which to compete and abundant resources such as light. If this is true, then mowing may actually keep vacant lots in an early successional stage, where ragweed is more competitive. This is corroborated by research that found ragweed to be a poor competitor in the environmental conditions produced by succession (Gebben, 1965; Pickett and Baskin, 1973; Leskovšek et al., 2012). In addition, when we conducted vegetation surveys in Detroit in 2011, we observed examples of vacant lots that were mowed regularly or occasionally and that had high ragweed densities (Katz and Carey, 2014).

The close association between ragweed populations and vacant lots implies that vacant lot management regimes could have serious public health implications for urban inhabitants with ragweed allergies. However, ecological theory suggests that mowing, the main management treatment for vacant lots and ragweed, could actually be promoting the conditions that ragweed thrives in. In order to clarify the impacts of mowing on ragweed populations, we conducted an observational study to address the following questions: (1) What are the mowing regimes for vacant lots in Detroit? (2) Are they correlated with ragweed presence and population density in vacant lots? (3) If so, can this be traced to succession and increased inter-specific competition? (4) Finally, which mowing regimes most effectively reduce ragweed populations?

Methods

Study area

We conducted our study in Detroit, MI, USA (42°19′ N, 83°02′ W), which has a humid continental climate, an average temperature of 10.6 °C, ranging from in −3.2 °C in January to 23.6 °C in July and an average annual precipitation of 940 mm (National Climate Data Center, 2013). Detroit's land use composition is strongly tied to its demographic and economic history. In the 1950s Detroit had 1.8 million inhabitants, but by the 2010 census, it was down to 713,777 (US Census Bureau, 2010). Depopulation has led to the widespread abandonment of buildings (according to the 2010 census, of 349,170 housing units in Detroit only 269,445 were occupied [US Census Bureau, 2010]); their subsequent demolition has resulted in Detroit having one of the highest proportions of vacant lots within the United States. Here, we follow the Detroit Residential Parcel Survey (2009) definition of a vacant lot as "a parcel with no structure and no improvement such as a paved lot, accessory structure, fence, or park." Management of these lots is conducted idiosyncratically by individuals or community groups, resulting in a wide range of mowing regimes, ranging from mowing every month to no active management. The large number of vacant lots and the wide array of mowing regimes make Detroit an ideal place to answer our study questions.

Vegetation surveys

We surveyed vacant lots in three neighborhoods in Detroit for ragweed. We selected vacant lots in two ways: randomly, using a random walk methodology (31 plots), and according to management type in order to increase the sample size of particular management types (31 additional plots). Sampling was conducted in October 2013. Although peak ragweed pollen abundance in the Detroit Metropolitan area in 2013 was in early September (Lake Saint Claire Shores Pollen Counting Station, *personal communication*), ragweed stems persist for several months after flowering, and were still easily identifiable in October. Some vacant lots contained multiple management types; one frequently observed pattern was that the front section of a vacant lot was mowed annually whereas the back half of the lot was unmowed. In this paper we report each of the different management types as a different vacant lot.

Within each lot we noted the mowing regime, which we categorized into one of the following categories of mowing frequency: monthly, annually, biennially, or unmowed. Because we did not have mowing records for these lots, we used the following criteria to infermowing regimes. Monthly: evidence of recent mowing (e.g., cut pieces of grass), and close cropped vegetation at an even height. Annually: cut stems evident, or growth forms typical of cutting were observed. Biennially: no cut stems visible, old field plants (e.g., *Solidago* sp., *Asclepias* sp., *Aster* sp.) present, but no woody plants beyond the seedling stage. Unmowed: no evidence of cut stems, woody plants present, and old field successional species abundant. Because our mowing regime criteria are based on our estimates of the time since last mowing, it is possible that a lot with an annual or biennial mowing regime could have been mowed just before we measured it, resulting in the plot being misclassified. However, we do not believe this is an important source of improper categorization, as we did not observe the cut stems of old field plants in any recently mowed plots. Moreover, any potential misclassification of lots (e.g., between the annual or biennial categories) would reduce differences between mowing categories, making the differences we did find between these mowing regimes more conservative. We recorded the maximum height of vegetation within the section of the lot surveyed to the nearest 0.5 m and whether woody plants were present. We also assessed whether ragweed was present in

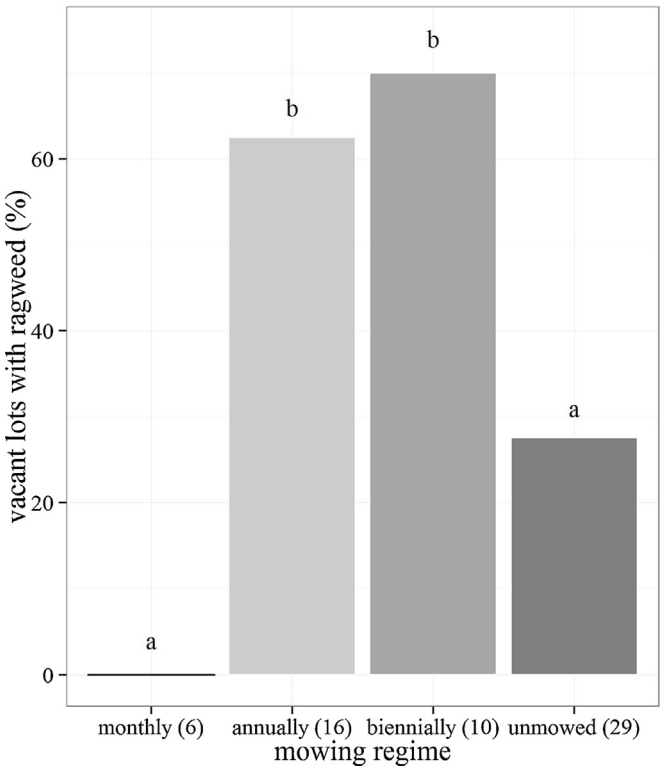

Fig. 1. Ragweed presence in vacant lots as a function of management. Sample sizes are given in parentheses and same letter annotation designates non-significant differences among management categories ($p < 0.05$).

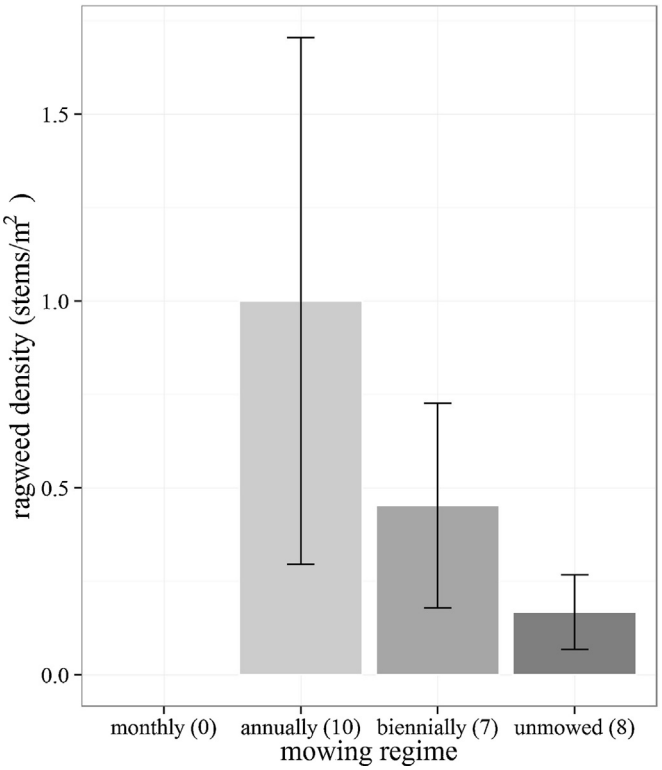

Fig. 2. Ragweed stem density in quadrats as a function of management. Sample sizes (the number of vacant lots where ragweed was present and stem density was measured) are given in parentheses. Error bars are standard errors; these differences were not statistically significant.

each vacant lot. In lots where ragweed was present, we randomly placed six quadrats, each of which was 1 m^2. Within each quadrat, we counted the number of ragweed stems present and measured the height of five randomly selected ragweed stems.

In order to test whether the relationships we observed were significant, we used proportion tests (Newcombe, 1998), *t*-tests, ANOVA, and linear regressions. All analyses were conducted in R 3.0.2 (R Development Core Team, 2013) and graphics were constructed using ggplot2 (Wickham, 2009).

Results

We surveyed a total of 62 vacant lots within three neighborhoods in Detroit. In our randomly selected sub sample of vacant lots, 16% were mowed monthly, 35% were mowed annually, 16% were mowed biennially, and 32% were unmowed. We found ragweed in a total of 25 of the 62 vacant lots. Vacant lots that were mowed intermittently (annually or biennially) were significantly more likely to have ragweed than lots that had been mowed monthly or were unmowed ($p < 0.05$; Fig. 1). Ragweed stem density within quadrats followed a similar apparent trend, with the highest ragweed stem densities in vacant lots that were mowed annually or biennially (Fig. 2), but the difference was not statistically significant ($p = 0.24$). However, the lack of significance is a better reflection of the sample size than the effect size (ragweed was only found in 17 quadrats). Ragweed density in quadrats ranged from 0 to 42 stems/m^2, and across all vacant lots where it occurred, it averaged 0.6 stems/m^2.

There were also relationships between ragweed and the other plants in vacant lots. Ragweed only occurred in lots where the maximum vegetation height ranged from 0.5 m to 2.0 m (Fig. 3); the mean maximum height in vacant lots with ragweed present was significantly shorter (0.95 m) than in lots without ragweed (2.30 m; $p < 0.01$), even though the latter category included many lots with short vegetation. Interestingly, although ragweed was more likely to occur in plots with lower maximum vegetation heights, when it did occur there was a significant linear relationship between ragweed stem height and maximum vegetation height ($p < 0.0001$, $R^2 = 0.40$; Fig. 4). However ragweed was never the tallest plant, and in plots with high maximum vegetation height, ragweed was relatively shorter than the tallest vegetation (as seen when comparing the linear regression with the one: one line in Fig. 4). Finally,

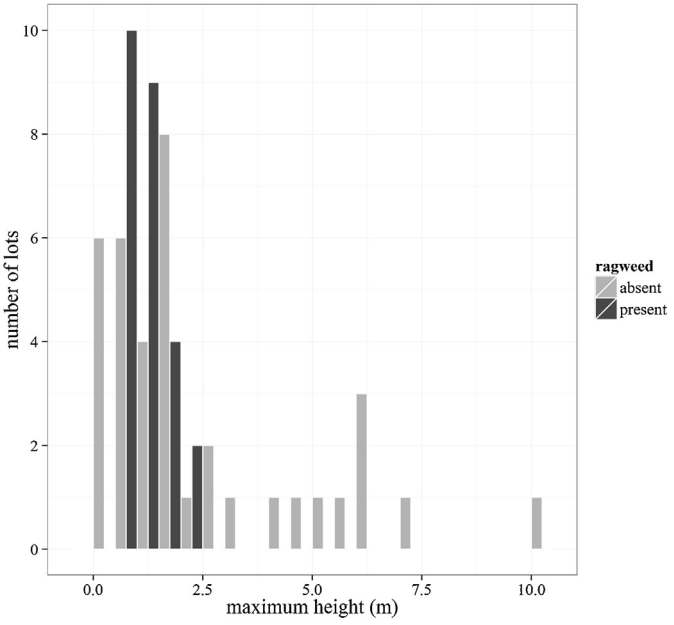

Fig. 3. Maximum vegetation height in vacant lots with and without ragweed present.

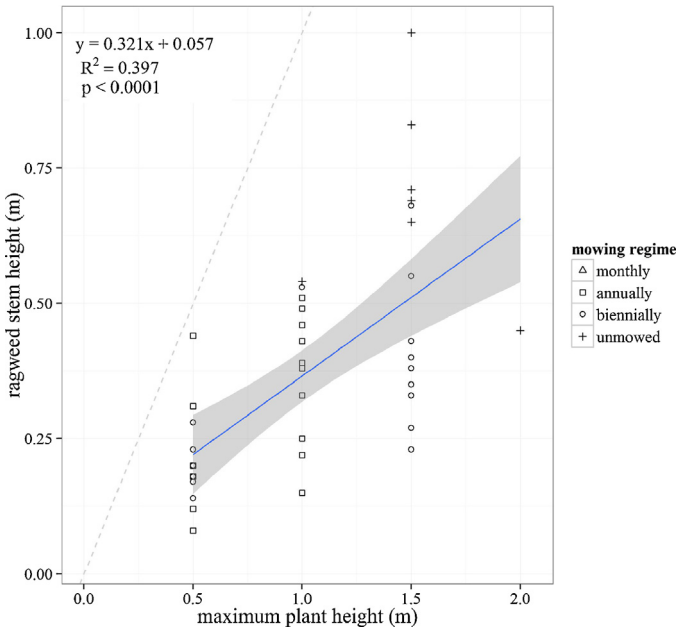

Fig. 4. Ragweed stem height as a function of maximum vegetation height. The regression line is shown (solid line) as is its 95% confidence interval (gray). The one:one line is also shown (dotted line).

our mowing regime classifications were supported by a significant relationship between maximum vegetation height and mowing regime; plots that had been mowed more recently had significantly shorter vegetation ($p < 0.0001$ for all pair wise comparisons).

Discussion

Effects of mowing on ragweed

We found that ragweed is most likely to be present in vacant lots that were mowed intermittently (annually or biennially). Our results are corroborated by experimental studies that found that while mowing once or twice a summer stunted ragweed growth, it still flowered and produced seed (e.g., Bohren et al., 2008; Simard and Benoit, 2011). One of the few studies that conducted a multi-year experiment in field conditions found that regular clipping (simulating mowing for hay) can actually increase western ragweed (*Ambrosia psilostachya* DC) dominance over time, albeit in a western tall-grass prairie system (Wan et al., 2002). Thus, although mowing annually or biennially does impact individual ragweed plants (as can be seen in the reduced height of ragweed in mowed plots; Fig. 4), this frequency of mowing actually increases the likelihood of ragweed being in a plot, indicating a positive impact on ragweed at the population level. Moreover, although our sample sizes were too small to be definitive, we found that ragweed stem density followed a similar pattern.

Ragweed and succession

We found that only 28% of the unmowed lots contained ragweed and within that subset of lots, ragweed density was very low (0.28 stems/m^2; Fig. 2). This result shows that ragweed populations decline when vacant lots remain unmowed. Various successional theories (as reviewed by Pickett et al. (1987) and Grime (2001)) predict that populations of early successional species, such as ragweed, will decline over time because of mechanisms such as competition for limiting resources or changes in the physical environment. It is likely a combination of these mechanisms for ragweed. First, inter-specific competition has been linked to lower resource levels such as light or nitrogen, resulting in suppression of ragweed (Raynal and Bazzaz, 1975; Kosola and Gross, 1999). There is also evidence that changes in the physical environment reduce ragweed populations. For example, experimental work by Ziska et al. (2007) found that experimentally established ragweed populations decreased over several years, in part because of the build up of leaf litter. Furthermore, fewer ragweed seeds germinate at low light levels or when buffered from temperature fluctuations (Pickett and Baskin, 1973), which results from seed burial. Thus, the presence of taller plants and more litter could result in fewer ragweed plants germinating. Regardless of mechanisms, we found that ragweed was not present in plots that had vegetation taller than 2 m. Similar results have also been found by Vincent and Bergeron (1985), who found that vacant lots with high densities of ragweed tended to have a far lower proportion of perennial plants, presumably because they were more recently abandoned and perennial plants had not established yet. Although ragweed stems tended to be taller in unmowed plots (Fig. 4), other researchers have found similar increases in ragweed height at low light levels (Gebben, 1965; Vermeire and Gillen, 2000). Increased height in those cases was correlated with decreased biomass (Vermeire and Gillen, 2000), smaller weight:height ratios (Vermeire and Gillen, 2000), and lower reproductive output (Gebben, 1965).

Recommendations for managing ragweed and the costs and benefits of succession in vacant lots

Our findings show that management of ragweed in vacant lots is best accomplished by either monthly mowing or not mowing at all. However, based on our sampling, most vacant lots in Detroit (51%) are mowed annually or biennially. We have demonstrated that leaving lots unmowed and allowing them to go through secondary succession can be an effective way to reduce ragweed populations. However, woody plant encroachment within the urban environment is often considered a symptom of urban blight (Solomon, 2014) and residents of Philadelphia neighborhoods with many vacant lots expressed concerns that "overgrown" vacant lots attract illegal dumping, crime, and unwanted wildlife (Garvin et al., 2013). In Detroit, elderly individuals reported that "vegetation overgrowth" discouraged them from walking in their neighborhoods (Gallagher et al., 2010). Still, maintained vacant lots with trees can improve neighborhood safety and health outcomes (Branas et al., 2011) and Detroit Future City, a collaboration between the city of Detroit and various private foundations and corporations, envisions and advocates for therefore station of vacant lots as part of its strategic framework for the future of Detroit (Detroit Future City, 2013). Regardless of the controversial nature of reforestation, we found that secondary succession is already occurring in many vacant lots in Detroit, which has the unexpected benefit of reducing ragweed pollen concentrations. Because one of the best ways to reduce future allergenic pollen loads is to intentionally select desirable plant species (Cariñanos and Casares-Porcel, 2011), it will still be important to manage later successional vacant lots for woody plants that are not major producers of allergenic pollen.

Conclusions

Ragweed has an important impact on human health, but traditional management approaches have proven ineffective in managing ragweed populations in the majority of vacant lots in Detroit. Although mowing yields short-term results and impacts individual plants, it is expensive and, if not done regularly, creates the conditions that allow future generations of ragweed to thrive. More detailed knowledge of ragweed's ecological relationships and natural history provides an alternative perspective on how to best manage ragweed. Ecologically informed management choices will

allow us to avoid the failures made by historical ragweed control efforts, which sought to control ragweed by mowing and simply ended up increasing it (Falck, 2010).

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