Invasibility of three major non-native invasive shrubs and associated factors in Upper Midwest U.S. forest lands

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ABSTRACT

We used non-native invasive plant data from the US Forest Service's Forest Inventory and Analysis (FIA) program, spatial statistical methods, and the space (cover class)-for-time approach to quantify the invasion potential and success ("invasibility") of three major invasive shrubs (multiflora rose, non-native bush honeysuckles, and common buckthorn) in broadly classified forest-type groups in seven Upper Midwest states. Smoothed maps of presence and cover percent showed a strong clustering pattern for all three invasive shrubs despite their different ranges. The species are clustered around major cities or urban areas (e.g., Chicago, Illinois, and Des Moines, Iowa), indicating the potential role humans played in their invasion and spread on the landscape and throughout the Midwest. Conditional inference tree (ctree) models further quantified the significant factors contributing to the observed regional patterns: for distribution of multiflora rose, percentage of forest cover in the county (measuring human disturbance intensity) and stand density index; for distribution of common buckthorn, distance to major highways. Non-native bush honeysuckles were not associated with any disturbance and site/stand variables except for latitude and longitude. The infested FIA plots by cover class were positively associated in space, signifying a concentric-like spread trend from previously infested sites (hot spots) to surrounding areas. By forest-type groups or as a whole, the three species spread slowly at earlier stages, but recently have increased significantly in presence/ expansion. Oak/hickory and elm/ash/cottonwood forests were more susceptible to the three invasive shrubs compared to other forests. We recommend that resource managers and planners prescribe control and mitigation treatments for non-native invasive plants by forest types and spatial locations close to highways and residences.

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1. Introduction

Non-native invasive plants (NNIPs) have been a part of North American ecological history for as long as human settlement. When NNIPs are introduced, either deliberately or inadvertently, they can employ various competitive characteristics, such as prolific seed production and dispersal, earlier flowering or leaf out, or vegetative expansion, and overwhelm native forest ecosystems that developed over centuries without such competition. The introduction of a species does not necessarily mean it will become established, however. Phenology, seed dispersal, site quality, and other factors influence whether a NNIP can become established. Once established, however, NNIPs can compromise native forest

structure, composition, function, and resource productivity (Webster et al., 2006; Boyce et al., 2012).

Previous research suggested that four factors influence invasion success: resource availability, disturbance, propagule pressure, and competitive release (Richardson and Pyšek, 2006). Whether a plant community or habitat is more easily invaded than others depends on how many potential invaders are present and whether the habitat is susceptible to invasion (Lonsdale, 1999; Richardson and Pyšek, 2006). Site productivity is one determinant of invasion success. Richardson and Pyšek (2006) found that resource availability facilitated invasiveness at larger spatial scales. Plant communities with high resource availability are particularly susceptible to invasion (Gelbard and Belnap, 2003). Elton (1958) suggested that high species diversity was important in resisting the establishment of non-native invasive species. He argued that a more diverse assemblage of species meant fewer unoccupied niches that would

provide an opportunity for invaders. Richardson and Pyšek (2006) reported studies that supported Elton's hypothesis, but also found others in which sites with a high species diversity harbor more alien species. They acknowledged Levine and D'Antonio's (1999) conclusion that species richness might be too coarse a factor to explain observed differences in community susceptibility to invasion, given that other factors (disturbance, nutrient availability, climate, and propagule pressure) are frequently covariates.

Disturbance reorders the available resources for plants, reducing it for some and increasing it for others, including invasive species. By upsetting the competitive balance and site occupancy of preceding plant communities, disturbances can make abiotic factors more important than biotic factors in determining the success of plant invasions (Richardson and Bond, 1991; Hood and Naiman, 2000). As the difference between gross resource supply and resource uptake becomes greater, a plant community becomes more vulnerable to invasion. Even temporary variations in resource availability, where they coincide with the arrival of invasive species, can result in successful invasions (Richardson and Pyšek, 2006).

NNIPs have characteristics that exploit the opportunities disturbances provide. Some invading species from the same genus as native species have a better chance of acclimatizing because they share preadaptations to conditions of this new region (Daehler, 2001). Additional research by Daehler (2003) concluded that invasive species have greater phenotypic plasticity than do native species inhabiting the same site, suggesting that common characteristics were less important than the unique ones. In other cases, invaders might benefit by being released from constraints present in their original habitat; others might evolve after their arrival in a new landscape or region (sensu Ellstrand and Schierenbeck, 2000). Unoccupied niches at the ends of the plant performance spectrum could provide opportunities for invasive plants to become established (Crawley et al., 1999). These niches might vary by site, size, or phenology (timing). Regardless, the interaction between invader and invaded is unique (Richardson and Pyšek, 2006) and depends on the context (Daehler, 2003).

Although it is sometimes possible to determine the date an invasive plant first arrived in the country, region, or even a particular site, the actual arrival date for most of the recent invasions is unknown. Estimating the initial arrival date is important, as the likelihood of establishment increases with the time since the original introduction. Where the initial introduction is unknown, scientists use the term "minimum residence time" (MRT). MRT integrates the time of potential establishment opportunity, the size of the supply of seeds or shoots, and (with expanding populations) the area from which the invasive materials originate (Richardson and Pyšek, 2006). Yet, MRT does not always correlate with the rate of spread. Plant invasions do not move continuously across the landscape; both local and long-distance transport can determine the spatial distribution (Pyšek and Hulme, 2005). Based on these analyses, one might conclude that exotic plant invasions spread more rapidly than natural migrations (sensu Richardson and Pyšek, 2006). Given the nature of inadvertent human transport, a significant factor in post-invasion spread rates (Hodkinson and Thompson, 1997), it would be difficult to predict the source and final destination of many invasive species.

Because one cannot always discern the exact starting point (in time and space) for an exotic plant invasion and quantify the finite amount of resources, managers need some indicator of success in managing invasive plant presence in order to best allocate their funds (Moser et al., 2008). One indicator of potential success of restoration efforts is the difference between the current state of an ecosystem and the desired state, perhaps based on historical evidence (Fulé et al., 1997; Moser et al., 2008). Those managers possessing sequential data points have many tools at their disposal

to determine the severity and rate of spread of nonnative invasive species (Higgins et al., 1996). Often, however, decisions are made with limited information, perhaps after the initial sighting or after only one survey. Given such a one-time inventory, assumptions must be made about the residence history of the found invasive, which allows a manager to postulate (1) the likelihood of restoration success and the level of investment necessary to eradicate the infestation, and (2) the expected rate of spread and the potential for more damage to the ecosystem (Fan et al., 2013). Although most invasive plant species can be analyzed this way, woody shrub species are particularly suitable subjects for this type of analysis. The above-ground biomass is more obviously cumulative and, barring disturbances that result in top-kill (e.g., fire), is in proportion to total plant biomass.

The major objective of this study was to evaluate the invasibility (invasion potential) and current condition of three important invasive shrubs: multiflora rose (*Rosa multiflora* Thunb. ex Murr.), non-native bush honeysuckles (*Lonicera* spp.; not differentiated by species), and common buckthorn (*Rhamnus cathartica* L.) in Upper Midwest forest lands as a whole, and by major forest communities using spatial statistics and the space-for-time approach. Specifically, we sought to answer the following questions: (1) What is the spatial pattern of the three species in terms of presence probability and cover percentage? (2) Does their invasibility differ among major forest communities? (3) What factors are associated with their current spatial patterns? These questions have not been answered at the individual species level and in a spatially explicit way in previous studies. Answering these questions will be critical for monitoring, management and decision making for the control and mitigation of these three common invasive shrubs in the Upper Midwest.

2. Data and methods

For the purposes of this paper, we define non-native invasive plants as those plants that (1) are not indigenous to the ecosystem ("non-native") and (2) have a competitive advantage that causes deleterious impacts on structure, composition, and growth in forested ecosystems ("invasive"). Considering the spatially nonstationary and temporally dynamic characteristics of the invasion and spread of an invasive species, we define invasibility as the susceptibility of a target region or forest community to the colonization and establishment of an invasive species and measure it in this study as the cumulative probability of plots in the US Forest Service's Northern Research Station, Forest Inventory and Analysis (FIA) program corresponding to a given threshold of cover (100 − cover) percentage of an invasive species. The cumulative probability (measuring colonization/occurrence) curve of cover (100 − cover) thresholds (measuring establishment) of an invasive species is a static measure of the invasibility of a region or forest community to an invasive species and the area under the curve can be used to compare the invasibility of different forest communities to an invasive species. During 2005–2006, the FIA program evaluated 8516 plots for presence and cover of any of 25 NNIPs (Olson and Cholewa, 2005; US Forest Service, 2005; Fan et al., 2013) across the 7 states in the Upper Midwest region of the United States. Of the 25 selected NNIPs, multiflora rose, non-native bush honeysuckles, and common buckthorn were the 3 most common invasive shrubs by presence. Multiflora rose had invaded 15.3% of the sampled plots, non-native bush honeysuckles had invaded 9.2%, and common buckthorn had invaded 4.8%; the degree of invasion was measured by percent cover (Fan et al., 2013).

All 8516 FIA plots were spatially referenced by latitude and longitude of the plot center and identified as to presence (1) or absence (0) of an invasive plant species (Moser et al., 2009). The