Exotic Plant Invasions in Successional Systems: The Utility of a Long-term Approach

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Abstract

Introduction. The limited temporal duration of most studies constrains our understanding of the dynamics of invasion, and the subsequent function of exotic species in plant communities. While most plant invasions occur over time periods of decades or longer, most experimental studies of invasions are brief, lasting only 1-2 years. These short-term studies, while providing detailed, mechanistic information, are expensive and time consuming and can only be done for a handful of problematic exotics. Similarly, observational sampling studies frequently only capture a single snapshot in time of community associations, yielding little information on pattern development. Both of these approaches do not account for the temporal variation characteristic of plant communities. We propose long-term vegetation monitoring as a complementary approach that provides information on pattern development at a whole-community level and can yield crucial management information. To illustrate the utility of this approach, we draw examples from a long-term study of successional dynamics.

The Buell-Small Succession Study (BSS). Since exotic plants commonly dominate abandoned agricultural land, successional studies, with continuous species invasions and losses, provide a unique opportunity to study the invasion of exotic species. Since 1958, a series of abandoned agricultural fields within the Piedmont region of New Jersey have been continuously sampled (Small *et al*. 1971; Pickett 1982). This study was initiated by Murray Buell, Helen Foot-Buell and John Small of Rutgers University and is located at the Hutcheson Memorial Forest Center in Somerset, New Jersey. The initial objective of their research was to document vegetation patterns in secondary succession. This landmark study has continued uninterrupted for 43 years, making it the longest, continuous study of secondary succession in existence.

The study consists of 10 fields, each containing 48 permanently marked 1 m^2 plots. The fields were abandoned over an 8-year span and with a variety of pre-abandonment agricultural treatments. Since abandonment, data collection has occurred every year until 1979, when sampling was switched to alternate years. At each sampling, the percent cover of all species present in each permanently marked 0.5 x 2.0 m plot is recorded. While the study was originally designed to examine successional changes in community composition, it is an ideal framework from which to address the problem of exotic plant invasions.

Successional patterns. Analysis of the BSS data has shown that the proportional abundance and diversity of exotic species has declined over the first 40 years of succession (Fig. 1; Meiners et al. in press). These declines appear to be in response to increased shading from canopy closure. Successional patterns suggest that management for later successional systems or for closed canopy forests should help to reduce the importance of shade-intolerant exotic plants (Robertson et al. 1994). While this result is encouraging from a management perspective, we have also observed recent increases in several species of shade tolerant exotics such as *Alliaria petiolata*, *Lonicera maackii* and *Microstegium vimineum*. Norway maple (*Acer platanoides*), an exotic tree species problematic in the Northeastern United States, has invaded the old- and second-growth forests of the

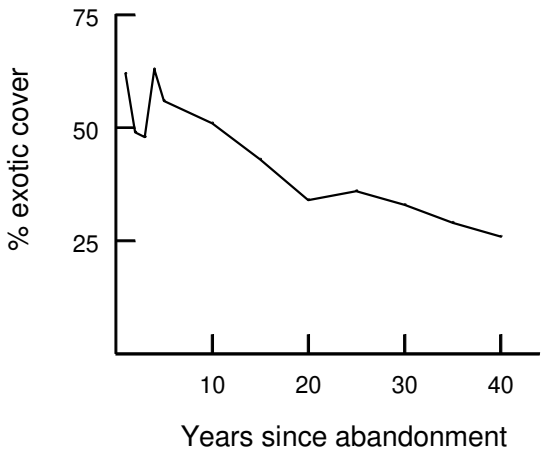

Figure 1.—Change in the proportion of exotic plant cover during succession in the 10 fields of the BSS.

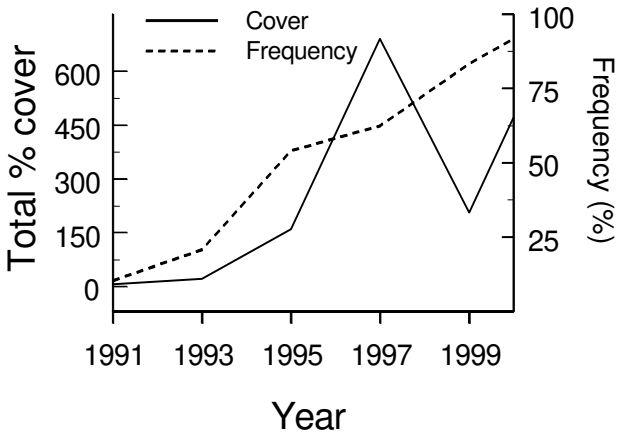

Figure 2.—Increase in cover and frequency of *Alliaria petiolata* in one BSS field.

Hutcheson Memorial Forest Center and has just begun to appear in the BSS fields. This new suite of invaders has the potential to persist within closed canopy forests and represents future threats to the biotic integrity of northeastern forests.

Invasion impacts on diversity. Community-wide vegetation sampling may also be used to set management priorities. Problematic exotic species are often found to cause declines in local diversity. To assess these impacts, we examined the influences of invasions on species richness for a large suite of native and exotic species. In this analysis, we focused on all species that 1) attained an average cover of at least 1% in a field and 2) became locally abundant (>66% cover) in at least five 1 m^2 plots. For each plot, the increase in cover of the invading species was related to the change in species richness during the invasion. Of the 25 native and exotic species studied only the native *Solidago canadensis* and the exotics *Agropyron repens*, *Lonicera japonica*, *Rosa multiflora*, and *Trifolium pratense* were associated with detectable decreases in species richness. These analyses revealed that relatively few species invasions have detectable influences on the diversity of plant communities. By determining which species are potentially damaging and thus management concerns, long-term vegetation monitoring can provide crucial information for land managers.

How should we measure invasions? Assessment of population growth is a crucial step in identifying new invasions and determination of the need for management intervention. Species invasions generally occur over fairly long time periods at regional scales but within-site spread may be quite fast. Knowledge about the rate of spread of a species within a site would be very helpful in determining the speed necessary for an effective management response However, it is not clear how these assessments should be made. There are two ways in which invasion rate may be assessed: as an increase in the frequency of an exotic species (plot occupancy) or as the increase in cover of a species (plot dominance). These two methods may be complementary or yield quite different results. In Figure 2 we show rates of increase for *Alliaria petiolata*, a shade-tolerant understory herb that has recently invaded the BSS fields. Within this field, the two indices of invasion differ in their temporal pattern. While cover of the plant was severely impacted by the 1999 drought, plot occupancy continued to increase. If we limit analysis to pre-drought increases, we find a linear pattern of increase for frequency and an exponential increase for cover. At least for this species in this field, the two indices are not analogous and describe different processes. Therefore, visual assessment of this invasion based on coverage would lead to problematic delays in management response that may result in the establishment of an uncontrollable population.

Rates of invasion. As previously mentioned, knowledge about rates of invasion can be very useful in timing control efforts. Invasions often show lag times, periods with little or no population growth, followed by rapid population expansion. The presence of a lag time may provide a useful window of opportunity during which management strategies can be devised and implemented. As an example, we provide an analysis of the rate of invasion for two woody vines common in the BSS fields (Fig. 3). Years 2-5 show a lag time for both species, with little increase in frequency. If analyses are restricted to the period following the lag phase, the rates of colonization are roughly linear. *Lonicera japonica* has a greater rate of spread than *Parthenocissus quinquefolia*.

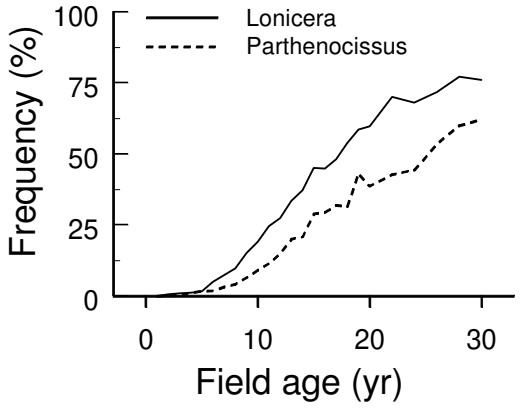

Figure 3.—Rates of invasions for the native *Parthenocissus quinquefolia* and the exotic *Lonicera japonica* in one field of the BSS.

However, the rate of spread for *Lonicera japonica* is much slower than that of *Alliaria petiolata* (Fig. 2), suggesting that management intervention to control *A. petiolata* would need to occur much more quickly.

Early detection of species invasions. Long-term vegetation data can have additional utility in detecting new invasions. Once vegetation monitoring protocols are in place, new species invasions can be detected before they become problematic at a local level. Continuous monitoring of permanent plots can also yield information about conditions associated with the species invasion and the subsequent consequences of the invasion. This information may allow land managers to address an invasion very early while management costs would still be quite low.

Conclusions

Long-term vegetation monitoring represents an approach to the study of exotic plant invasions that is complementary to detailed manipulative studies. While direct mechanistic results are not possible with monitoring data, these studies provide 1) data directly addressing temporal variation in exotic populations, 2) methods for assessing management priorities, 3) estimates of within-site rates of spread, and 4) a framework for the detection and evaluation of new species invasions. These data, coupled with manipulative case studies of exotic plants, can provide a well-rounded knowledge base from which to make effective management decisions.

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