

2002 Progress Report: Predicting the Distribution and Dominance of Exotic Species in Southern Appalachia

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Title: Predicting the Distribution and Dominance of Exotic Species in Southern Appalachia

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Research Category: Exploratory Research to Anticipate Future Environmental Issues:
Biopollution

Description:

Displacement of native species by invasive exotic species is one of the most serious types of "biopollution" and is a major threat to biodiversity worldwide. Over the past few years, several field studies (Stohlgren et al. 1999; Lonsdale 1999) have found results that contradict a central tenet of the classical ecological theory of invasibility, calling into question the conclusion that high species diversity confers resistance to invasion. The primary objective of this project is to develop a method for predicting spatial patterns of exotic species invasion and dominance across landscapes, as well as the time period over which a particular exotic species is likely to be a problem in a given area. We will also determine the degree to which the physiology and life history traits of invasive species are correlated with the spatial patterns of invasion, specifically with patterns of disturbance and resource availability. This will allow prediction of which environment a particular exotic species is most likely to invade, whether its effect will be severe or minor, and how long it is expected to be a problem, in relation to changes in environmental conditions caused by natural successional changes.

Objective :

Test ecological theory of invasions based on environmental properties, and develop a method for predicting spatial patterns of exotic species invasion and dominance across landscapes, as well as the time period over which a particular exotic species is likely to be a problem in a given area. The approach taken here differs from the traditional approach to understanding plant invasions, which focused on the properties of species, specifically those properties that made them more "weedy" or "invasive." Our approach is based on the dynamic equilibrium model of species diversity, and assumes that both native and exotic species respond similarly to environmental conditions, particularly those related to mortality-causing disturbances and resources necessary for growth. This model predicts that the most favorable conditions for plant establishment and survival (and consequently, high species diversity) should occur where physical conditions allow survival of most species but competitive interactions are weak and competitive exclusion occurs slowly, if at all. These conditions predicted to occur where resource availability (and thus plant growth and productivity) is low and disturbances are infrequent, but also where plant resource availability is high and mortality-causing disturbances are frequent (see Huston 1979, 1994).

([Figure 1a](#)). One corollary is that the diversity of native and exotic species should be positively correlated. This prediction is the opposite of classical competition theory, which predicts that the correlation should be negative, because communities with a high diversity of native species should be more resistant to invasion than communities with low diversity. In addition, the model predicts that plant dominance should be highest, and thus the potential impact of invasive species greatest, under productive conditions where competitive exclusion occurs more rapidly ([Figure 1b](#)). Our model of invasions thus predicts the probability and intensity (impact) of plant invasions, as well as the probable duration of the survival of a population of exotic species, based on the rate of competitive exclusion. This project will test these predictions using a combination of field surveys and experiments.

Progress Summary:

The first year's activities focused on the spatial patterns of exotic and native plant species distributions on the landscape of the Oak Ridge National Environmental Research Park, near Knoxville, Tennessee. This landscape has a unique history because of its role in the Manhattan Project during World War II. Prior to the war, this area was rural and isolated, with much of the population engaged in subsistence agriculture and living in log cabins. Most of the landscape was in cultivated fields and pasture, with a relatively small proportion in forest. In 1942, the entire population was evicted and relocated, and the area was secured for the top-secret activities of the Manhattan Project. The entire landscape, with the exception of 3 isolated areas dedicated to nuclear research and production, was abandoned and natural succession allowed to occur. Most of the landscape is now forested, and relatively undisturbed outside of the roads, powerline rights-of-way and the three Manhattan Project facilities.

The distribution of vegetation sampling plots was designed to sample topographic variability on 3 major ridge-forming geological formations on the Oak Ridge National Environmental Research Park, located Ridge and Valley physiographic province near Oak Ridge, Tennessee. Two transects one kilometer in length, one initiated at the base of the north-facing slope and one at the based of the south-facing slope were established on Black Oak Ridge, East Fork Ridge, Pine Ridge, Chestnut Ridge, Haw Ridge, and Copper Ridge, with sample plots every 50 meters. Each multi-scale sample plot was composed of three 1x1m plots for species cover estimates, nested within a 5 x 5 m and a 10 x 10 m plot in which all species were identified. With sample plots every 50 m, the twelve transects contained 240 10 x 10m sample plots, with 720 1x1m plots with cover and height measurements for all species. Sampling focused on understory vegetation, both herbaceous and woody, native and exotic. Ancillary data include forest basal area by species, canopy openness, litter mass, and soil pH, carbon and nitrogen in the 0-10 cm layer.

All plots were visited at least three times during the growing season to identify species differing in phenology and to determine the identities of all species present. Field data were quality-checked and entered into Excel spreadsheets, and the GPS locations of all plots entered into a MapInfo GIS. Vegetation sampling was completed by mid-October, 2002.

Preliminary analysis indicates that our sample plots encountered approximately 480 out of the total of 1100 plant species recorded on the Oak Ridge Reservation. Of these, 37 species were non-native, out of the total of 167 non-native species recorded on the reservation. Most of the 37 exotic species occurred at very low frequencies, with only three species present in more than 10% of the 240 10 x 10m plots ([Fig. 2](#)). Thus, after 60 years of recovery the formerly agricultural landscape is now covered by forest with a relatively low incidence of exotic species.

Other patterns of interest from the preliminary analyses include a negative correlation of forest basal area with the cover and species richness of both native and exotic species, with a more rapid decline of exotic species richness than of native species richness. We also found a positive correlation between the number of native and the number of exotic species per plot, which has also been reported in several larger-scale surveys published over the past several years. This positive correlation is consistent with our model of invasibility, but contradicts the predictions of classical invasion theory.

Future Activities:

Plans are being developed with the research and resource management staff in Great Smoky Mountain National Park to examine radial patterns of native and exotic species abundance in relation to back-country campgrounds. Some campgrounds, particularly those that have been used by horses, have a high incidence of exotic species, while campsites used by hikers only have very few exotic species. We will use a transect approach similar to that used on the Oak Ridge Reservation to sample patterns of native and exotic species richness around campsites in different major vegetation types within the park. In addition, we will carry out resource manipulation experiments (light, water, soil nutrients, leaf litter) on the Oak Ridge Reservation to test hypotheses related to environmental constraints on the spatial distribution of common exotic species.

Publications and Presentations: Total Count: 5

<u>Type</u>	<u>Citation</u>
Journal Article	Predicting the probability, intensity, and duration of invasions by exotic plant species” Diversity and Distributions, in review. [abstract]
Presentation	Huston, M.A. Predicting the distribution, impact, and duration of plant invasions. Invited symposium presentation. 28th Natural Areas Association Conference, Cape Canaveral, FL, October 2001. [abstract]
Presentation	Huston, M.A. Predicting the distribution, impact, and duration of plant invasions. Invited presentation. Southeast Exotic Pest Plant Council Conference, Nashville, TN, April, 2002.
Presentation	Huston, M.A., L. Pounds, J.W. Johnston, Jr.. The distribution of native and exotic plant species across a recovering landscape in eastern Tennessee. 29 th Natural Areas Conference, Asheville, NC, October, 2002. [abstract]
Presentation	Huston, M.A., L. Pounds, J.W. Johnston, Jr., and G. Barlar. Testing a theory of plant invasions with data from the Oak Ridge Reservation. Great Smoky Mountain National Park Headquarters, Gatlinburg, Tennessee. November, 2002.

Supplemental Keywords: plants, invasions, invasibility, exotics, ecology, diversity, disturbance, understory, forest, succession, soils, nutrients, topography, southeast, appalachia, agriculture, restoration, recovery, *Microstegium*, *Lonicera japonica*.

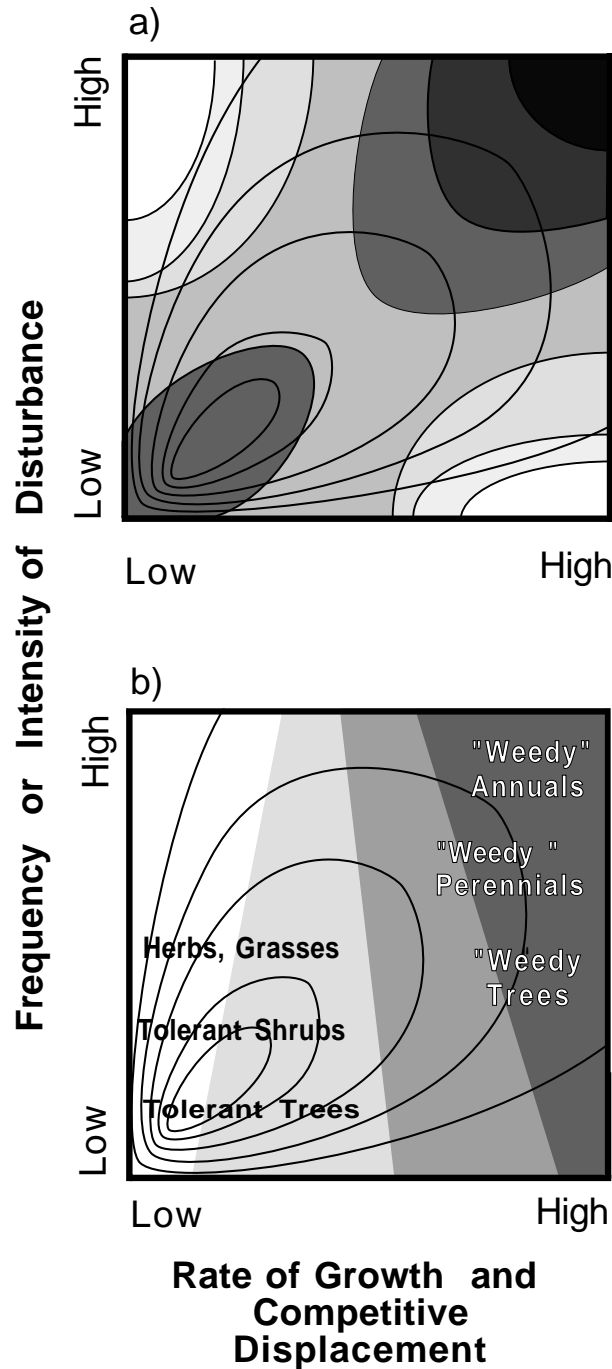


Figure 1. Predicted community susceptibility to establishment and dominance of invading species in environments classified according to disturbance and productivity (Huston 1979). a) Predicted susceptibility of communities to invasion. Darker shading indicates higher susceptibility. Ellipses indicate the predicted contours of species diversity, with the highest diversity within the smallest ellipse in the lower left. Note that communities with low diversity are least likely to be invaded successfully, and communities with high diversity are most likely to have invaders establish successfully. b) Predicted dominance and life histories of successful invaders under various combinations of productivity and disturbance. Shading indicates expected dominance of a community by a successful invader. (from Huston 1994).

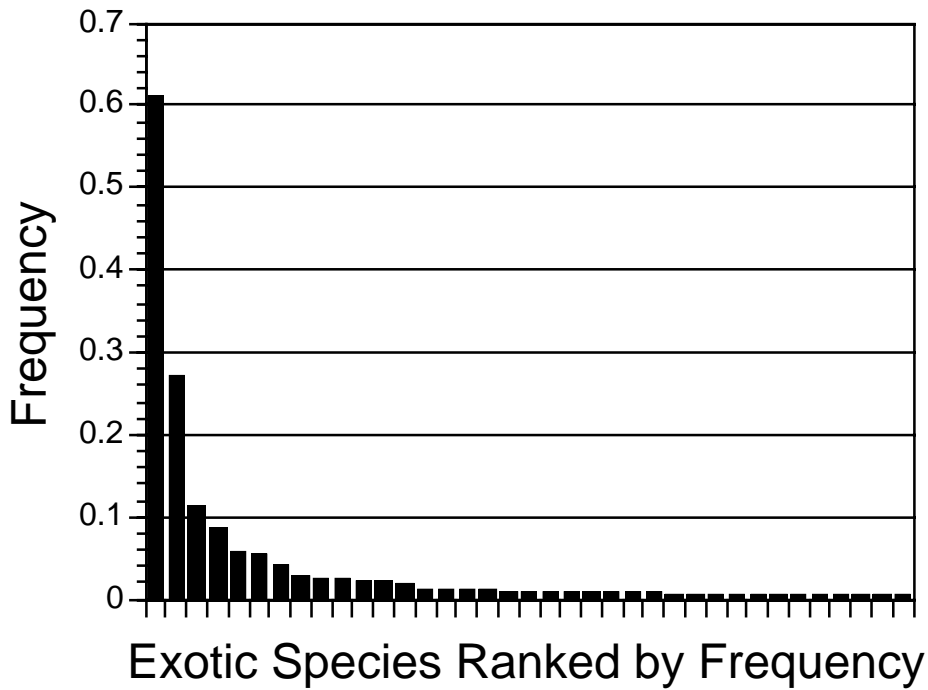


Figure 2. Ranked frequencies of exotic plant species encountered during systematic sampling of landforms and geological formations of the Oak Ridge Reservation in eastern Tennessee. Most of the landscape is forested. Frequencies are based on presence in 240 completely censused 10 x 10 m plots, distributed as 12 transects 1 km in length, with 10 x 10 m sample plots every 50m. Note that only three out of 37 species were present in more than 10 percent of the plots. These species were *Lonicera japonica*, *Microstegium viminium*, and *Ligustrum sinense*.

Abstract of Submitted Paper

Predicting the Probability, Intensity, and Duration of Invasions by Exotic Plant Species

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The traditional approach to understanding invasions has focused on properties of the invasive species and of the communities that are invaded. A well-established concept is that communities with higher species diversity should be more resistant to invaders. However, most recently published field data contradict this theory, finding instead that areas with high native plant diversity also have high exotic plant diversity. An alternative approach to understanding patterns of invasions focuses on properties of the environment related to the survival and competitive interactions of organisms. This approach assumes that native and exotic species respond similarly to environmental conditions, and thus predicts that they should have similar patterns of abundance and diversity. Population responses and species diversity are predicted in relation to the interaction of productivity and population growth rates with the frequency and intensity of mortality-causing disturbances. The approach distinguishes between the probability of establishment, and the probability of dominance, predicting that establishment should be highest under unproductive and undisturbed conditions and also disturbed productive conditions. The probability of dominance by exotic species, and thus of potential negative impacts, is highest under productive conditions, which is also where native species can achieve high dominance. The theory predicts that a change in disturbance regime can have opposite effects in environments with contrasting levels of productivity. Manipulation of productivity and disturbance provides opportunities for resource managers to influence the interactions among species, offering the potential to reduce or eliminate some types of invasive species.

Abstract of Oct. 2001 Natural Areas Association Invited Presentation

HUSTON, MICHAEL A. Interdisciplinary Solutions for Environmental Sustainability, Inc. Oak Ridge, TN. Environmental predictors of the probability, intensity, and duration of invasion by exotic plant species.

The traditional approach to understanding and predicting invasions by exotic plant species has been based on assessing the properties of the potential invaders in relation to the properties of the resident species. Most predictions of this traditional ecological theory have been contradicted by observed patterns of plant invasions. An alternative theory, based on non-equilibrium dynamics rather than the competitive equilibrium of traditional theory, makes predictions that disagree with those of classical theory, but closely match observed patterns of plant invasions. The Dynamic Equilibrium Model predicts community dynamics, species diversity, susceptibility to invasion, and other ecological and ecosystem properties in terms of the effects of environmental conditions on the interaction of plant growth rates (primary productivity) with disturbances that kill or damage plants. This model predicts that the probability

of successful invasion (by native or exotic species) should be highest under the environmental conditions that allow high species diversity, which is the opposite of the prediction of classical ecological theory. In contrast to the pattern for the probability of successful establishment, the probability of dominance by exotic species, which is to say, serious problems caused by the invaders, is highest under productive conditions where native plant diversity is typically lower. Different “functional types” of plants are expected to have different spatial patterns and temporal dynamics of invasion. Various examples of problem invaders will be discussed in relation to this theory.

Abstract of October 2002 Natural Areas Association Presentation

THE DISTRIBUTION OF EXOTIC AND NATIVE PLANT SPECIES ACROSS A RECOVERING LANDSCAPE IN EASTERN TENNESSEE. Michael Huston¹, Bill Johnston¹, Larry Pounds¹ and Gregory Barlar¹. ¹Interdisciplinary Solutions for Environmental Sustainability, Inc. Oak Ridge, TN, USA, 37830 (865) 483-8563. mahustonor@comcast.net.

ABSTRACT: In 1942 over fifty square miles of fields, pastures, and woodlots in the Ridge and Valley Province near Knoxville, Tennessee were purchased for the Manhattan Project. Most of this land is still protected as the Department of Energy's Oak Ridge Reservation. Some of the landscape remains highly disturbed as roadsides, powerline rights-of-way, pine plantations, and military-industrial facilities. However, most of the landscape has undergone natural forest succession, beginning from a variety of starting conditions, and is now covered with hardwood forests dominated by oaks, hickories, and yellow poplar. We have extensively sampled the vegetation of this area using multi-scale plots positioned every 50 meters along twelve 1 km linear transects. Our objective is to test the hypothesis that invasibility can be predicted from the interaction of site productivity and disturbance regime, and specifically that areas with high native plant diversity will also have high diversity of exotics. Species such as *Lonicera japonica* and *Microstegium vimineum* are widespread, but abundant only in a narrow range of conditions. Our preliminary conclusion is that forest succession has reduced or completely eliminated many previously abundant exotic species.