Response of Exotic Invasive Plant Species to Forest Damage Caused by Hurricane Isabel

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RESPONSE OF EXOTIC INVASIVE PLANT SPECIES TO FOREST DAMAGE CAUSED BY HURRICANE ISABEL

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ABSTRACT

In September 2003, Hurricane Isabel caused unexpectedly high levels of wind damage to an 80- to 100-year-old forest in the Piedmont of Maryland. The storm had decreased in intensity from landfall by the time it reached the study site—sustained winds were moderate and maximum gusts recorded in the area were only 62.7 mph (28.1 m·s^{-1}). Mid-sized gaps (up to 1 ha) were created in forest that historically had only small or single-tree gaps.

Isabel created the opportunity to determine whether natural disturbance facilitates the spread of exotic invasive plant species. Exotic invasive species populations were sampled in 400 5 x 5 m quadrats in a heavily damaged 1-ha, long-term forest study plot and in 160 5 x 5 m quadrats in 0.4 ha of a nearby, less-damaged forest between mid-October and mid-December 2003. Light levels (quantum flux density of photosynthetically active radiation) in the heavily disturbed Permanent Plot and the Less Damaged control plot were surveyed in October 2003 and 2004. The fall 2004 resurvey for exotic plants has also been completed.

Based on a random sample of the fall 2004 exotics data, exotic invasive plant species responded strongly to the increased light levels in patches of forest damaged by Isabel. Collectively, the mean increase in percentage cover of exotic plants was 47.8% in high-light canopy gaps versus only 4.8 % in low-light non-gaps and 4.2% in the less-damaged forest. Several individual exotic species—*Polygonum perfoliatum*, *Polygonum caespitosum*, and *Lonicera japonica* had significant positive responses to higher light levels. The shade-loving biennial, *Alliaria petiolata*, changed significantly in the opposite direction, decreasing in the high-light areas and increasing in the low-light areas.

The authors are also investigating the interaction of exotic plants with native plants, forest regeneration, and white-tailed deer (*Odocoileus virginianus*) in damaged areas. Study areas and exclosures for these projects were set up in 2004 and will be resurveyed beginning in 2005.

INTRODUCTION

Remnants of Hurricane Isabel passed across the Maryland Piedmont the night of 18–19 September 2003. The storm had decreased considerably in intensity by the time it reached central Maryland. It produced about 5 cm of rain locally (Dickerson, MD, author's rain gauge). Winds were moderate. Maximum sustained winds in Dickerson were 37.2 mph (16.7 m·sec^{-1} [1]). Maximum gusts recorded within a 50-km radius were 62.7 mph (28.1 m·sec^{-1}) [2]. This was a moderate-level storm, not a severe hurricane, yet it created unexpectedly large amounts of damage to forests [3].

Based on patterns of tree fall from Hurricane Isabel, the susceptibility to wind damage for canopy trees has been found to increase with tree size [3]. As forests age and trees grow larger, moderate winds are likely to cause more damage, both by uprooting trees and by snapping them off. As the probability of wind damage for individual trees increases, the pattern of damage shifts from small, or single-tree gaps to larger patches of disturbance. Therefore, it is predicted that in the future, forests in the Mid-Atlantic states will be increasingly subject to medium- and large-scale damage from moderate winds [3].

Hurricane Isabel provided an unexpected opportunity to study the response of exotic invasive plants to natural disturbance. These plants often respond positively to disturbance [4]. Disturbed ecosystems typically have more resources available to colonizing or invading plants than undisturbed ecosystems. This situation is well documented for anthropogenic disturbances, such as timber harvest, road building, and utility right-of-way construction [5]. Natural disturbances (such as flooding, high winds, and fire) perturb forests and make light, space, and disturbed soil available to invading plants, increasing establishment, survival, and growth [6]. The high winds and flooding of a hurricane, which typically occur near the end of the growing season when plants have already set seed, can also increase the dispersal of exotic plants. The spread of exotic organisms has been linked to hurricanes in the past. Forest damage from Hurricane Gilbert in 1988 facilitated the spread of exotic *Pittosporum undulatum* (Cheesewood) in the Blue Mountains in Jamaica [7]. Forest damage from Hurricane Eva in 1982 was linked to the spread of *Schefflera actinophylla* (Octopus tree) in a preserve in the Limahuli Valley on Kauai, Hawaii [8, 9]. Recently, Hurricane Ivan in 2004 was suspected of bringing the spores of Asian soybean rust (*Phakopsora pachyrhizi*) to Louisiana from South America [11]. A strong positive response by exotic plants to predicted and increasingly frequent natural disturbances in eastern deciduous forest would have serious implications for natural resource management and the conservation of rare forest plant species.

METHODS

Work on exotic plant invasion following Hurricane Isabel has focused on the West Woods site, a pre-existing forest plot in Dickerson, Montgomery County, Maryland (39.21º N, 77.42º W). The 1-ha Permanent Plot (PP) was set up in 1998 to study forest growth and succession. The 100 x 100 m plot was subdivided on a 10-m grid into 100 10 x 10 m quadrats. The size, growth, and mortality of trees in the forest had been surveyed for five years before Isabel. The forest was heavily damaged by the storm, with 23.5% of the canopy trees severely damaged, comprising 25.1% of the basal area [3]. The damage was patchy, with both undisturbed areas and canopy gaps up to roughly 1500 m^2. Following the hurricane, the plot was subdivided into 400 5 x 5 m quadrats. A 0.4-ha control plot was set up in comparable but less-damaged forest south of the Permanent Plot called the Less Damaged Plot (LDP). Both plots were surveyed for the presence and cover of exotic plant species between mid-October and mid-December 2003. Since Isabel arrived near the end of the growing season, negligible new growth of herbaceous vegetation had occurred between the storm’s passage and the fall 2003 survey. In addition, the plants being surveyed were woody, evergreen, or had persistent dried plant parts after senescence. Thus, the fall 2003 survey provided an unbiased sample of the exotic plant population before significant effects or disturbances occurred due to the passage of Hurricane Isabel.

Removal of the forest canopy increases light levels at the forest floor, but in an irregular and continuously varying fashion. The storm did not leave discrete patches of severely damaged trees in a matrix of undisturbed forest; there are no unambiguous “gap edges” around the blowdowns. In other words, damaged forests are not Swiss cheese [11]. Light levels at the forest floor were used as a measure of the disturbance to the tree canopy by Isabel rather than through definition of “gaps” and “non-gaps.” Measuring light allows direct use of a resource made available by Isabel, rather than an arbitrary classification of gap status, to evaluate plant response to the hurricane. Furthermore, light levels in the gaps are not fixed; the amount of light in a gap is roughly proportional to the size of the damaged area. Using light levels differentiates between small, one- or two-tree gaps, and more extensive blowdowns in evaluating plant response. Finally, additional light from canopy gaps penetrates into surrounding undamaged forest. Light effects from hurricane damage may be present tens of meters into still-closed canopy forest. Measuring actual light levels captures this spillover effect. Other effects of hurricane damage may influence the growth of exotic invasive plants, particularly soil disturbance, changes in soil nutrients, and changes in soil moisture. Others have found that soil resources change little following a simulation of hurricane damage [12]. If such effects do occur, they would tend to be spatially correlated with canopy damage. Changes in light levels may not be the entire reason for changes in the herbaceous layer, but these changes should be good markers for storm effects.

Light levels were measured for the PP and LDP plots in October 2003 and 2004 with two paired light meters (LICOR LI-250). Quantum flux density of photosynthetically active radiation was measured simultaneously at the 10-m intersection points of the 1999 plot grids and in a nearby, open field. Readings were taken at 55 points in the LDP and 121 points in the PP. Measurements were taken of diffuse, indirect light in early morning and late evening with continuous 15-sec readings. Timing of readings was coordinated to the nearest second with handheld radios.

The “end-of-year-one post-Isabel” fall survey of exotic plants began on 17 October 2004. The same order of survey was followed as in the fall of 2003 to minimize the effects of any seasonal differences in vegetation. Thus, each quadrat was being surveyed within a week of the date of survey in 2003. As of 12 November 2004, 360 of 560 quadrats had been resurveyed.

Hurricane Isabel left behind a less-than-optimal experimental design. While the control plot is in all measurable ways similar to the Permanent Plot (surrounding land use, forest age, land use history, forest cover, soil, slope, aspect, initial herbaceous cover, percentage in floodplain), completely randomizing disturbance effects throughout the less damaged, low-light, and high-light quadrats was not possible. There is minor clumping of the high- and low-light quadrats due to the patchy distribution of storm damage, but the quadrats are well dispersed across the plot. Quadrats were selected randomly but are not entirely independent, again due to the nature of natural disturbance. Given that the West Woods plot was set up years before the hurricane and was thus random with respect to storm damage, it is suggested that the problems related to independence of samples are acceptable.

RESULTS AND DISCUSSION

The light surveys have demonstrated the extent of damage to forest canopy. Mature forest is dark. After Isabel, light increased almost an order of magnitude in heavily damaged areas. The mean light level in the selected quadrats in the LDP was 3.2 % of ambient light (n = 15). Mean light levels in the high-light and low-light quadrats in the PP were 24.7 % and 3.9% respectively (n = 15 each). Clearly, the storm increased a limited resource on the forest floor.

Eight species of exotic plants were located in the PP and LDP in fall 2003, with frequency of occurrence ranging from 0.18% for English ivy, (*Hedera helix*, 1 of 560 quadrats) to 87.8 % for Japanese honeysuckle (*Lonicera japonica*). The biennial garlic mustard (*Alliaria petiolata*) was also common, occurring in 79.6% of the quadrats. These common plants tended to be sparse, typically covering less than 1% in quadrats. Multiflora rose (*Rosa multiflora*) was less common, occurring in 55.5% of the 560 quadrats, but individual plants covered large areas, exceeding 50% of some quadrats.

In the first year following the hurricane, exotic invasive plants have responded vigorously to the change in light levels. Percentage cover for random samples of 15 quadrats each from the three light environments were compared: closed canopy forest in the LDP; high-light areas in heavily damaged sections of the PP; and low-light areas in the relatively undamaged sections of the PP. Mean percentage cover by exotic plants responded strongly to growing in high-light areas (Figure 1). The mean changes in percentage cover of exotic invasive plants in LDP, high-light PP, and low-light PP quadrats between 2003 and 2004 were 4.2%,

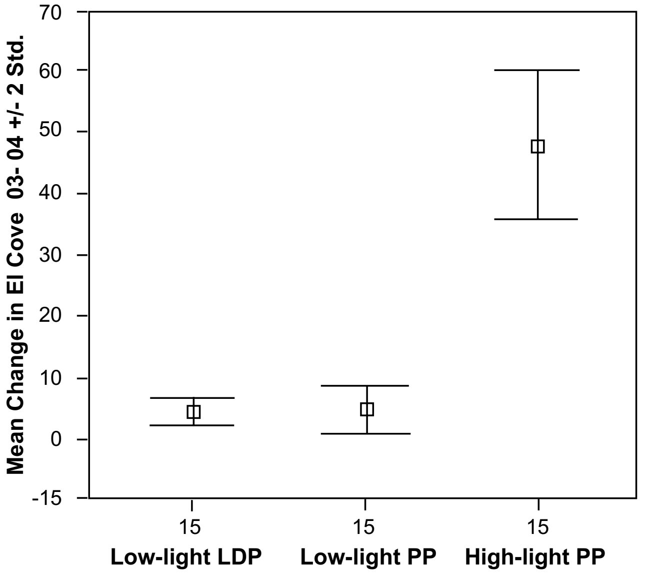

Figure 1. Change in percent cover of exotic invasive plants in plots with differing canopy disturbance levels between fall 2003 and fall 2004. LDP and low-light PP are not significantly different. High-light PP and the other two treatments are significantly different (P < 0.05).

4.8%, and 47.8% respectively (significantly different by a Kruskal-Wallis test, P < 0.001). The frequency of occurrence of exotic plants also changed between 2003 and 2004 (Table 1).

Broken down by species, exotic plant cover has changed significantly for four out of fifteen species since the hurricane. This response is strongly related to the three different light environments. Increased percentage cover for mile-a-minute (*Polygonum perfoliatum*), long-bristled smartweed (*Polygonum caespitosum*), and Japanese honeysuckle (*Lonicera japonica*) is in each case significantly greater in the high-light than in the low-light and LDP areas (Table 1). Garlic mustard (*Alliaria petiolata*) also changed significantly, but with increased coverage in the shady quadrats and decreased coverage in the high-light quadrats. The cause of this decrease is not known. Garlic mustard may be decreasing due to competition from other invasive plants. But since garlic mustard is a biennial, the observed decrease in cover may be due to a difference in distribution of the alternate-year cohorts.

The species with a significant increase in the light-rich blowdowns are two annuals that did not exist in the plots before Isabel (mile-a-minute and long-bristled smartweed) and a widely dispersed perennial (Japanese honeysuckle) that was already in place in the disturbed patches. Less widely dispersed perennials also increased in frequency and cover in the high-light areas, but not significantly.

These results are important because a change in the herbaceous layer influences forest succession [13]. Dense herbaceous vegetation can increase seed predation on large-seeded trees such as oaks. Exotic plants growing in high-light field edges near this research site form dense mats of vegetation and overwhelm less aggressive plants. Native vegetation is suppressed or replaced by exotic invasives [14]. High densities of exotic plants also alter ecosystem function. Nutrient cycling, hydrology, and food webs are altered when exotic plants replace native ones [4, 15, 16, 17]. High populations of exotic plants reduce populations of native plants and threaten local extinction for uncommon plants. The forest that regenerates in the 21st century, responding to increasingly frequent wind damage [3] and an herbaceous layer dominated by exotic plants, will differ from the forest that would have regenerated hundreds of years ago.

This exotic survey is part of a long-term assessment of the interactions between exotic invasive plants, the native plants in the herbaceous layer, forest regeneration, and elevated populations of white-tailed deer in natural areas in the Mid-Atlantic region. Both exotic and native plants in the herbaceous layer were surveyed in May 2004 and again in May 2005 (and later) to evaluate the effect of disturbance and exotic spread on native plant populations. Tree seedlings are also being monitored to assess the interaction of exotic plants and canopy tree regeneration.

Deer could be influencing the spread of exotic plants and regeneration of the forest. Exotic plants leave behind most of their co-evolved herbivores [18]. If deer are avoiding exotics and browsing preferentially on native plants, deer browsing pressure could increase the growth, survival, and spread of exotic plant species. While working on this and other projects at the same site, deer browse on garlic mustard, Japanese stiltgrass

Table 1. Change of percent cover in 5 x 5-m quadrats between fall 2003 and fall 2004, by species and type of plot. P values are from Kruskal-Wallis tests for significant differences between plots with Bonferroni correction. Significant changes in percent cover are in boldface.

Species	Change in % cover '03-'04, LDP	Change in freq., low-light LDP	Change in % cover '03-'04, low-light PP	Change in freq., low-light PP	Change in % cover, 03-'04, high-light PP	Change in freq., high-light PP	Change in % cover
Polygonum perfoliatum (Mile-a-minute)	0.0	0	0.0	0	2.00	46.7	**<0.001**
Rosa multiflora (Multiflora rose)	-0.50	13.3	0.17	6.7	2.17	20.0	0.137
Alliaria petiolata (Garlic mustard)	1.33	53.3	0.33	13.3	-0.17	-6.7	**0.001**
Lonicera japonica (Japanese honeysuckle)	0.17	6.7	-1.00	-6.7	3.67	13.3	**0.005**
Rubus phoenicolasius (Wineberry)	0.33	13.3	0.33	13.3	4.17	40.0	0.160
Glechoma hederacea (Gill-over-the-ground)	0.17	6.7	0.33	13.3	0.67	26.7	0.540
Duchesnea indica (False strawberry)	0.17	6.7	1.00	6.7	11.17	0	0.081
Polygonum caespitosum (Long-bristled smartweed)	2.50	100.0	3.33	100.0	24.00	86.7	**0.002**
Total	4.17	25.0	4.83	18.3	47.83	28.3	**<.001**

(*Microstegium vimineum*), or mile-a-minute has not been observed. Deer also serve as dispersal vectors for exotic plants. Deer eat fruit and pass viable seeds from exotic plants [19]. The weed seeds that stick to clothes evolved to take advantage of animals for dispersal, not wool socks and cotton sweatshirts. Deer exclosures have been set up in damaged and less-damaged forest to evaluate the impact of deer on exotic plant spread.

If natural disturbance triggers the interactions suggested here, forest regeneration could be altered or suppressed. Populations of native wildflowers will be reduced or replaced. Forests in the future could end up quite different from the historic forests of the Mid-Atlantic states.

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