Biological Invasions **4:** 369–373, 2002.

The potential impact of an introduced shrub on native plant diversity and forest regeneration

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Received 10 January 2001; accepted in revised form 27 November 2002

Key words: biodiversity, Chinese privet, *Ligustrum sinense*, mixed hardwood forest, tree regeneration

Abstract

Over a period of 20 years, Chinese privet, *Ligustrum sinense*, invaded a mixed hardwood forest in western North Carolina, USA. The invasion penetrated about 30 m under the canopy trees, providing 100% cover of the forest floor. Under the privets and in a nearby privet-poor reference area we marked off twenty, one square meter plots with string. All plants in each square meter of both areas were tallied in the spring of 1999 and young trees less than 1 m high were again counted in September. We removed privets of the invaded area in November and again tallied all plants in both areas the following spring of 2000. In the spring of 1999, the mean number of herb species per square meter under the privet was 41%, and stem counts 75% less than in the reference area. 42% of herb species found in the reference area were missing under the privet. After removing the privets in the fall of 1999, the number of both native species and stems increased in the 'privet' area the following spring. Plots of density of two native plants against privet density showed both native plants decreasing under increasing privet cover. In the spring of 1999, there were 4 species and 274 stems of tree seedlings in the privet area. In September of that year, we found only one small American holly tree, a highly shade-tolerant species, remaining under the privet. Our data support the thesis that Chinese privet can severely reduce herbaceous species and almost completely suppress tree regeneration in a mixed hardwood forest.

Introduction

When organisms are transported from the biological communities in which they evolved into new and undisturbed, natural communities, they usually do not survive without human help. Some, however, with a combination of characteristics that allow largely uncontrolled reproduction, may become invasive (Reichard and Hamilton 1997; Mack et al. 2000; Randall 1996). When this happens, considerable damage to their new community may result. Because of increased human movements and commercial transportation, there is an accompanying amount of organism transport and accumulating biological damage around the world (OTA 1993; Vitousek et al. 1996).

Transported plants that become naturalized in new communities may cause several kinds of damage. Perhaps their most common impact is the competitive exclusion of native plants and associated animals at the new site. For example, an Australian tree, *Melaleuca quinquenervia*, has replaced cypress, saw grass and many other native species in some 160,000 ha of south Florida, USA (Schmitz et al. 1997); *Mimosa pigra* trees, invading over 80,000 ha of tropical wetlands of Australia, have displaced native plants as well as water birds (Braithwaite et al. 1989); in the Cape Province of South Africa, the invasion of non-indigenous eucalyptus, pines, *Acacia*, and *Hakea* threatens the extinction of many endemic floral species of the Cape (van Wilgen et al. 1996); in coastal scrub areas of

California, USA, the invading succulent, *Carpobrotus edulis*, can overgrow native vegetation and competitively reduce both sun exposure and xylem pressure in adjacent native plants (D'Antonia and Mahall 1991); in the dunes of Indiana, USA, an invasion of black locust trees, *Robinia pseudoacacia*, has been shown to reduce the diversity of herbaceous species and to facilitate the spread of the non-indigenous grass, *Bromus tectorum* (Peloquin and Hiebert 1999); on the island of Maurtius, exotic trees were found to make up 21–35% the of trees and 74–97% of tree seedlings in wet forest remnants (Lorence and Sussman 1986).

Invasions of non-indigenous plants have also been shown to be associated with loss of native animals. For example, in tropical Australia, the invasion of *Mimosa pigra* is associated with lowered density of birds and lizards (Braithwaite et al. 1989); in southwestern USA, *Tamarix ramossisima* infestations have been associated with 2× decrease in richness and a 4× decrease in abundance of macroinvertebrates (Bailey et al. 2001). In addition to these types of effects, invasive plants have also been implicated in changes in soil nitrogen and associated biota, the frequency and intensity of fire, altered nutrient and hydrological cycles, sediment deposition, and erosion. For a review, see Randall (1996).

In this paper, we narrow the perspective to the possible effects that one plant, Chinese privet (*Ligustrum sinense* Lour), might have on the native vegetation of a mixed hardwood forest. Field observations seemed to show reductions of herbaceous plants under thick patches of privets. If privets were in fact causing a reduction of native vegetation under their foliage, we would expect to find a significant lowering of native plant diversity and/or abundance under the privets in comparison to a privet-free reference area. In this report, we examine this expectation by recording tallies of plants both under the privets and in an adjacent, privet-poor reference area.

Methods

Chinese privet, *Ligustrum sinense* Lour., is a native of China and was introduced into the USA in 1852 for use in hedges and landscaping (Dirr 1990; Wyman 1973; USDA 2002). It has been sold widely and still appears in commercial nurseries and landscaping (Bailey and Bailey 1976; USDA 2002). The plant grows most rapidly in habitats with abundant sunlight but readily invades shady forests, especially in stream floodplains. In 1998, Chinese privet was recorded in the eastern United States from Massachusetts down along the Atlantic coast and into most of the southern states as far west as Texas (USDA 1998).

The site selected for this study was a mixed hardwood forest in Henderson County of western North Carolina. It was unusual in that it was the only site we could find, despite extensive searching, where a heavy infestation of privet existed close to a relatively privet-free area in the same forest with the same aspect, soil, and history of use. For this study, infested and reference areas were only 10 m apart and showed a marked and uniform difference in privet abundance: the infested area contained a dense patch of privet shrubs/trees while the reference area contained only a few, scattered and small privet plants.

A drainage ditch, dug years ago along one edge of this forest by a farmer, has old privet trees four inches in diameter growing on its banks. From this ditch, privets had spread about 30 m into the forest with decreasing size and age. A large privet adjacent to our tallying area contained 18–19 growth rings in the main trunk. Foliage of the privets produced 100% coverage of the forest floor under a closed tree canopy. The tree canopy consisted mostly of *Liriodendron tulipifera*, *Acer rubrum*, *Prunus serotina*, *Cornus florida*, and *Oxydendrum arboreum.* Judging by the trunk diameters of the largest trees, the forest had last been cut 75–100 years ago. The forest floor showed no signs of human disturbance with an east-facing slope of a few degrees.

We marked off with string and stakes twenty 1 m^2 plots within both infested and reference areas. All plants in each square meter of both areas were tallied as number of species and number of stems per square meter. The first tally was done in June 1999. In late September, we tallied all trees less than 1 m high. In November, we cut off at the base and removed all privet plants from the infested area. In June 2000, we again tallied both areas. Finally, we compared means of the numbers of species or stems per square meter in each area by t-tests with $n = 20$.

Black cherry seedlings (*Prunus serotina* Ehrhart) and violets (*Viola papilionacea* Pursh) were found in such abundance in June 1999 that we were able to plot the relationship between their numbers and the number of privet stems per square meter using data from both areas.

Table 1. Comparison of number of species and number of stems per square meter in privet-infested and reference areas in June of 1999 and 2000.

	Trees				Herbs			
	No. of species		No. of stems		No. of species		No. of stems	
	1999	2000	1999	2000	1999	2000	1999	2000
Reference	2.1	2.9	18.5	23.8	5.9	8.0	39.5	42.0
Privet-infested	2.5	2.2[a]	13.9	22.4	3.5[a]	6.4[a]	10.0[a]	50.2
% change	+19%	−24%	−25%	−6%	−41%	−20%	−75%	+20%

[a] t-test shows difference between privet-infested and reference to be significant at $t < 0.05$.

Table 2. Total number of tree species and stems less than 1 m high in privet-infested and reference areas in June and September 1999.

	June 1999		September 1999	
	No. of species	No. of stems	No. of species	No. of stems
Reference	8	361	5	32
Privet-infested	4	274	1	1

Results

In June 1999, there were no significant differences between privet and reference areas in the mean number of tree species or tree stems per square meter (Table 1), although the total number of tree species and stems in the privet area was markedly smaller than in the reference area (Table 2). However, in that same year the number of herbaceous species and stems were significantly fewer under the privet: 41% less in mean species and 75% less in mean stems per square meter, relative to the reference area (Table 1).

In September 1999, a tally of trees less than 1 m high revealed a profound difference between privet and reference areas. In the reference area, a total of eight species and 361 stems found in June had been reduced to five species and 32 stems in September (Table 2). Under the privet, however, the June total of 4 species and 274 stems had been reduced to one small tree, American holly, *Ilex opaca* Aiton, a highly shade-tolerant species (Table 2).

After the tree tally in September, all privets in the privet area were cut off at the base and removed. A tally of the 'privet' area in the spring of 2000 showed about the same number of tree species per square meter as the previous year but a marked increase in number of stems per square meter (Table 1). Similarly, herbaceous species in the 'privet' area showed substantial increases in both number of species and number of stems per square meter (Table 1).

We looked at individual species of the reference and 'privet' areas to see what actual species were missing under the privet. There was net loss (Table 3) of 42% of the reference herb species and 50% of tree species in fall of 1999. Those differences had been reduced to a net loss in the 'privet' area of 33% of herbs and 25% of trees in the spring of 2000 (Table 3).

If privets were actually causing the observed difference in number of species and stems, we would expect a negative correlation between privet density and number of associated native plants. Black cherry seedlings and violets were found in such abundance in both reference and privet areas in 1999 that we were able to combine data from both areas and plot the density of each native plant as a function of privet density. Scatter plots with both plants showed negative tendencies amid the scatter with $r = -0.42$ for black cherry trees and $r = -0.29$ for violets. To make the actual slopes clearer, we aggregated the numbers of privet stems per square meter into groups of five then plotted means and standard errors (Figure 1). We see negative correlations with both native plants.

Discussion

Exclusion of native plants by non-indigenous invaders is a common observation by field workers and has been documented many times. For example, salt cedar (Bailey et al. 2001), several exotic plant species (Lorence and Sussman 1986), and black locust (Peloquin and Hiebert 1999) have been shown to exclude and reduce native plants. We could find nothing about explicit impacts caused by Chinese privet in the literature, but several of its negative effects, observed in natural communities, have been summarized recently (USDA 2002).

Table 3. Species missing from the privet-infested, as compared with the reference area.

	No. of species				Net species[a] missing in privet		Total species in reference		% of reference species gone	
	Only in privet		Only in reference							
	1999	2000	1999	2000	1999	2000	1999	2000	1999	2000
Herbs	3	4	13	12	10	8	24	24	42	33
Trees	0	2	4	4	4	2	8	8	50	25

[a]Net species = total number of species only in the reference area minus the total number of species only in the privet-infested area.

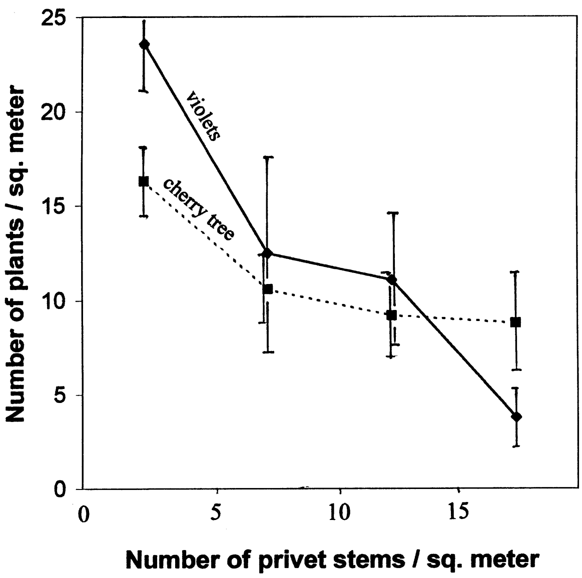

Figure 1. Mean number of black cherry tree seedlings and violets per square meter as a function of the number of privet stems per square meter.

In this study, we used quantitative methods to compare adjacent areas of a mixed hardwood forest with and without privet invaders. We selected a privet infestation that provided 100% cover of the underlying forest floor. Although we searched extensively for other sites where privet was found in high density and close to a privet-free reference area with identical characteristics, we could find no others that were similarly suitable. Therefore, our application of t-tests to compare the means of twenty replicates in each area represents statistical pseudoreplication. Nevertheless, the tests provide a measure of reliability of the differences recorded within the variances encountered.

All of our data are consistent with the thesis that privet actually causes a reduction in herbs and tree seedlings beneath it: both herbs and trees show fewer species and fewer stems under privet; there is a negative correlation between the density of two native species and the density of associated privet; tree seedlings under privet disappear during the summer; when privet is removed, both herb and tree seedlings show an increase in the number of species and stems in the next growing season.

It is important in considering these findings to remember that it is only a snapshot in time and almost certainly not a terminal, equilibrium condition. Looking under the much older privet trees along the ditch at the edge of the forest, from which our observational plants undoubtedly came, reveals almost nothing growing except privet shoots and a few vines. It seems probable that as the privets in this forest age, increasing in number and size, the disappearance of underlying plants will continue as their seed beds become exhausted and perennial plants that predate the privet invasion weaken and die off.

We conclude that privet-infested forests without privet control will probably undergo degenerative changes over time with heavy reductions of biological diversity. Larger studies of this invading plant, which document changes over time and probe mechanisms such as allelopathy, seem indicated.

Acknowledgements

This work was done on one of the preserves of the North Carolina Chapter of The Nature Conservancy. We are grateful for the support provided by the Science and Stewardship Division of the Chapter and for the help of its administrator, Sam Pearsall.

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