

Effect of an invasive ground cover plant on the abundance and diversity of a forest floor spider assemblage

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Abstract Ground dwelling spiders are important predators in the detrital food web, which plays important roles in nutrient cycling and energy flow in forest ecosystems. The cursorial spider assemblage in a Beech-Maple forest in southwestern Michigan at sites where and invasive plant, *Vinca minor*, has invaded was compared to a native site within the same forest and to the forest prior to invasion by the plant. Pitfall traps were used to sample cursorial spiders over the course of a summer. *Vinca minor* substantially altered the forest floor spider assemblage. The invasive plant reduced the total activity-abundance of spiders by nearly 49% and depressed species diversity and evenness; in contrast, species richness was not affected. We found that *V. minor* changed the guild and family structure with wolf spiders being common at sites where the plant had invaded. *Vinca minor* reduced the abundance of vagrant web building and crab spiders. Similarity indices revealed that the spider communities between the two sites were quite dissimilar (Bray-Curtis = 0.506; Jaccard's = 0.520). Importantly, comparison to a study conducted in the same forest 28 years earlier showed that the cursorial spider assemblage in the forest prior to *Vinca* invasion was very different than it was after *Vinca* invaded but was

similar to the current native site in species and guild composition. We conclude that invasion by *Vinca* has caused the striking changes we observed in community organization of this important group of forest floor predators. We suggest that changes in the physical structure of the litter/soil microhabitat with the invasion of *V. minor* are likely the cause of the substantial impacts of the plant on the spider assemblage.

Keywords Beech-maple forest · Detrital food web · Michigan · Spiders · *Vinca*

Introduction

While invasions by alien plants is implicated in major ecological changes in a variety of habitats (Mack 2000), their impact on the native arthropod fauna has received comparatively little attention. Invasion of *Spartina* salt marsh by *Phragmites* in New Jersey was associated with reductions in species richness and diversity when considering the entire arthropod assemblage (Gratton and Denno 2005). While generalizations are difficult to make given limited data, it appears impacts of invasive plants on arthropods are most pronounced for arthropods that feed on plants (Ernst and Cappuccino 2005; Herrera and Dudley 2003), yet when invasive plants are phylogenetically related to native plants, this may not be the case (Agrawal and Kotanen 2003). Indirect impacts of

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invasive plants on other trophic levels are even less clear. Ernst and Cappuccino (2005) studied an invasive vine in old fields and found it was associated with reduced abundance of ground dwelling arthropods, although impacts on plant-dwellers were more pronounced. Invasion of giant reed into riparian habitats in California tended to reduce ground dwelling arthropod abundance and diversity, but differences with native vegetation were not significant (Herrera and Dudley 2003). Similarly, invasion by garlic mustard into forests of central New York did not affect ground beetle assemblages (Davalos and Blossey 2004).

Arthropods of detrital food webs in forest leaf litter play important roles in nutrient cycling and energy flow. For example, one group of litter-dwelling arthropods, the spiders, annually consumes 43.8% of the arthropod biomass in a North American deciduous forest (Moulder and Reichle 1972). Spiders are not only important members of the detrital food web, they also appear to be a stabilizing predatory force on invertebrate communities in natural (Riechert and Lawrence 1997; Wise 1993) and agricultural ecosystems (Agusti et al. 2003; Hlivko and Rypstra 2003; Riechert and Bishop 1990; Sigsgaard 2002). Therefore, any changes in the spider assemblage caused by disturbances, like alien plant invasion, could have important ecological effects.

Vinca minor (Apocynaceae) is a common plant throughout the northeastern US. The plant was imported from Eurasia in the 18th century as a ground cover used in shade gardens (Darcy and Burkart 2002; Wyman 1977). It occurs in at least 36 states, has escaped cultivation, and is invading natural forest ecosystems (Swearingen et al. 2002). It forms a dense blanket of groundcover in forests (Swearingen et al. 2002) at rates somewhat slower than assigned by Richardson et al. (2000) for “invasive”, but its depression of recruitment by native plants argues for the label invasive. It is a good competitor in shade (Hottes 1947) and strongly reduces the recruitment of native tree seedlings on the forest floor (Schulz and Thelen 2000), apparently due to shading (Darcy and Burkart 2002). The plant has received considerable attention for the indole alkaloids that it produces and the potential use of these in treatment of human disease (i.e., Kruczunski et al. 1998). The purpose of our study was to

determine impacts *V. minor* may have on the assemblage of spiders that inhabit the floor of a beech-maple forest in southwestern Michigan, USA.

Methods

Study site

We sampled cursorial spiders at the Hope College Nature Preserve (HCNP). It is a dune successional forest along the eastern shore of Lake Michigan, 12 km SW of Holland, Michigan, USA. It is dominated by American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), black maple (*Acer nigrum*) and to a lesser degree, black cherry (*Prunus serotina*) and red oak (*Quercus rubra*). The understory consists of saplings of canopy trees, scattered shrubs like maple-leaf viburnum (*Viburnum acerifolium*) and spicebush (*Lindera benzoin*) and a variety of herbs. The forest is transitional between the beech maple ecoregion that is characteristic of southern Michigan and the northern hardwoods ecoregion to the north (Bailey 1976; Delcourt and Delcourt 2000) due to the moderating influence of Lake Michigan. While the site is not pristine, differences between the species composition observed and that expected on the basis of published categorizations of the region’s vegetation are probably due the complexity of local climate variation (K.G. Murray pers. comm.). Annual sampling by college ecology classes of size distributions of trees suggests that the forest is slowly recovering from some selective logging that occurred in the first quarter of the 20th century (K.G. Murray, pers. Comm.). Portions of the HCNP forest have been invaded over the past 35 years by the herb, *Vinca minor*, a common ornamental ground cover.

Field sampling

To sample cursorial spiders, 10 pitfall traps were used at a site where *V. minor* had not invaded (hereafter native site) the forest and nine pitfall traps were used within a patch of *V. minor* invasion (hereafter *Vinca* site) (only nine traps were used here due to the limited area of the patch, ca. 80 m × 35 m). While *V. minor* has invaded several portions of the forest, at only one site (the one sampled) has the plant formed a

dense mat on the forest floor. This is likely the initial site of colonization, which may have occurred through dumping of yard waste along the forest edge. As a consequence, we were only able to sample at one *Vinca* site. Sites were ca. 200 m from one another. Pitfall traps consisted of a polypropylene cup (15 cm dia) placed within a metal sleeve which was inserted flush with the soil surface of the ground (Bultman et al. 1982). About a 10 cm depth of propylene glycol, anti-freeze, was used as the preservative at the bottom of the trap. Traps were covered with a square wooden roof, raised 3 cm above the soil surface by four legs (Bultman et al. 1982). Pitfall traps were placed along two transects within each site, with an intertrap distance of 10 m. Every week from 6 June 2005 to 24 August 2005, pitfall samples were filtered through a screen and spiders were placed into jars with 70% ethanol to be identified later. After samples were collected each week, traps were recharged with preservative.

Lack of multiple sites with *V. minor* in the forest prohibited replicate sampling and constrained our ability to make extensive statistical tests. This was compensated for by comparing data collected herein to those from a study on the cursorial spider assemblage at the HCNP conducted in 1977 (Bultman et al. 1982), before *V. minor* had begun to invade the forest or, if present, was at very low density. Sampling for that earlier study was also done by pitfall traps; some of which were located in the vicinity where *Vinca* has subsequently invaded. The sampling protocol of the previous study was identical to the methods used in the present study (see Bultman et al. 1982). The pre-*Vinca* study allows us to compare the cursorial spider assemblage before and after *Vinca* invasion and to compare the current native site to the forest floor spider community 28 years earlier.

The use of pitfall traps has been questioned due to certain variables influencing the results like weather, differential species activity and trap placement (Greenslade 1964; Southwood 1966; Turnbull 1973). Proponents defend the method because of its versatility in different habitats and continuous sampling (Breymer 1966, Curtis 1980; Gist and Crossley 1973). Furthermore, it was shown to be an adequate estimator of the number of species of cursorial spiders over a wide range of habitats (Bowen et al. 2004; Jennings et al. 1984; Uetz and

Unzicker 1976; Bultman 1992). Pitfall traps do not estimate the density of cursorial spiders but instead estimate the “active density” or the number of cursorial spiders moving in an area for a given time (Uetz 1977; Bultman et al. 1982). Differences in spider abundance between native and *Vinca* sites were assessed by repeated measures ANOVA.

Characterization of community structure

Guild and family composition of cursorial spiders was compared among all sites. Species overlap between the sites was compared with two similarity indices: (1) Jaccard's (1908) coefficient, $S_j = a / (a + b + c)$, where “a” is the number of species collected at both sites A and B, “b” is the number of species collected at site B but not A, and “c” is the number of species collected at site A but not B, and (2) the Bray Curtis similarity index:

$$1 - \frac{\sum_{i=1}^n |N_{1i} - N_{2i}|}{\sum_{i=1}^n N_{1i} + N_{2i}}$$

where N_{1i} and N_{2i} are the numbers of the i th species at sites 1 and 2, after log transformation ($\ln(X + 1)$) of the data (see Clifford and Stephenson 1975). Thus, while Jaccard's coefficient depends only on presence/absence, the Bray–Curtis index depends upon the number of each species present. Additionally, species richness, species diversity using the Shannon (1948) index, and evenness (H'/H'_{\max}) were calculated. Dominance diversity curves (Whittaker 1975) were also constructed to compare the spider communities from the sampling sites.

Results

Comparison between *Vinca* and native sites

The presence of *V. minor* was associated with lower total spider active density (Table 1, $F_{1, 9} = 19.00$, $P < 0.01$). Species diversity was also lower for the *Vinca* site as was evenness (Table 1). In contrast, species richness was unaffected by the presence of the invasive ground cover plant (Table 1).

Cursorial spider guild composition was strongly altered by *V. minor*: vagrant web builders, sit and wait predators, and running spiders all decreased in

Table 1 Abundance and diversity of wandering spiders at native and *Vinca* sites in a beech-maple forest in southwestern Michigan, USA

	Site		
	Native	Vinca	Pre-Vinca*
Vagrant web builders			
Amaurobiidae			
<i>Callobius bennetti</i>	37	1	5
Agelenidae			
<i>Agelenopsis utahana</i>	4	0	4
<i>Cicurina brevis</i>	1	1	2
<i>C. pallida</i>	9	2	1
<i>C. robustus</i>	0	0	2
<i>Coras medicinalis</i>	1	0	0
<i>Wadotes calcaratus</i>	24	4	22
Hahniidae			
<i>Neoantistea magna</i>	274	9	80
Hunting spiders			
Lycosidae			
<i>Pirata montanus</i>	0	200	0
<i>Lycosa terricola</i>	0	7	0
<i>Schizocosa ocreata</i>	0	0	2
Pisauridae			
<i>Pisurina mira</i>	0	1	0
Running spiders			
Gnaphosidae			
<i>Drassylus virginianus</i>	89	31	0
<i>Haplodrussus signifer</i>	0	1	0
<i>Sergiolus variegatus</i>	3	0	0
Clubionidae			
<i>Agroeca ornata</i>	1	5	3
<i>Castianeira cingulata</i>	36	2	3
<i>Clubiona kastoni</i>	0	1	0
<i>Phrurotimpus alarius</i>	3	0	24
<i>P. borealis</i>	10	0	33
Anyphaenidae			
<i>Anyphaena pectorosa</i>	1	4	0
Sit & wait predators			
Thomisididae			
<i>Philodromus premix</i>	2	0	0
<i>Xysticus elegans</i>	7	3	2
<i>X. ferox</i>	5	8	0
<i>X. fraternus</i>	76	3	31
Salticidae			
<i>Paraphidippus marginatus</i>	2	1	0
<i>Habrocestum pulex</i>	0	1	0

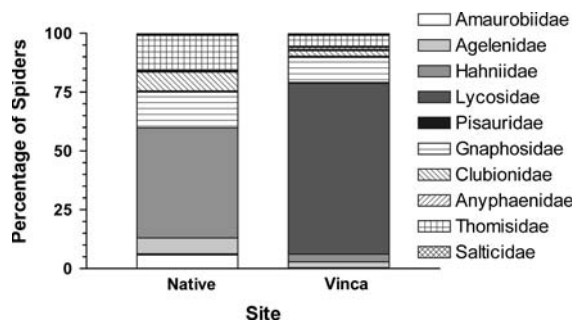
Table 1 continued

	Site		
	Native	Vinca	Pre-Vinca*
<i>Neon nelli</i>	0	0	4
N	585	285	218
S	19	19	15
H'(base 10)	0.743	0.540	0.820
J	0.581	0.422	0.697

* from Bultman et al. (1982)

relative abundance in the presence of *V. minor* (10, 1.5, and 2.8-fold decreases, respectively). In contrast, hunting spiders were very common, making up nearly 75% of the relative abundance of spiders at the *Vinca* site, but were completely absent from the native site (Fig. 1).

Inspection of family composition revealed that hahniid spiders dominated the spider community of the forest floor at the native site (Fig. 2) and that this was due solely to one species: *Neoantistea magna* (Table 1). While this species also occurred at the *Vinca* site, its abundance was greatly reduced (Table 1, Fig. 2). Members of the Thomisidae were diverse at both sites (Table 1), but their abundance was greatly reduced in the presence of *V. minor* (3-fold decrease in relative abundance, Fig. 2). Gnaphosids experienced a 1.4× decrease in relative abundance at the *Vinca* site. The presence of *V. minor* was associated with the addition of six species that were not found at the native site (Table 1). Most notable of these were the lycosids, *Pirata montanus* and *Trochosa terricola*, the former of which was the most common species at the *Vinca* site.

**Fig. 1** Family composition of cursorial spiders at native, *Vinca*, and pre-*Vinca* sites within a beech-maple forest in southwestern Michigan, USA

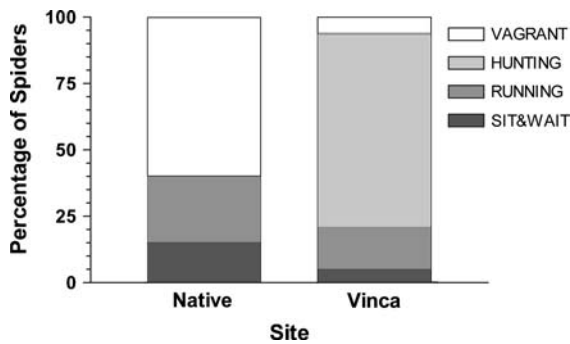


Fig. 2 Guild composition of cursorial spiders at native, *Vinca*, and pre-*Vinca* sites within a beech-maple forest in southwestern Michigan, USA

Both Jaccard's Coefficient and the Bray Curtis Index showed that similarity between the spider communities at the two sites was moderate (Table 2). While both communities had 19 species, only 13 occurred at both sites (Table 1). Species diversity was lower at the *Vinca* site, at least in part because of reduced evenness (Table 1).

Dominance diversity curves for the two communities graphically showed differences in community structure that mirror differences in species diversity. The presence of *V. minor* shifted the curve to the left and increased the initial slope (Fig. 3) due to the numerical domination by *P. montanus*.

Comparison of native and *Vinca* sites to pre-*Vinca* invasion

Data from the pre-*Vinca* sampling are presented in Bultman et al. (1982) and are not fully presented here. Even though the two sampling efforts are separated by 28 years, the cursorial spider communities in the native and pre-*Vinca* samplings were quite similar. Of the 15 spider species collected in the pre-*Vinca* sampling [note: only 11 were included in the previously published data set; *Agelenopsis utahana*, *Callobius bennetti*, *Neon nelli* and *Wadotes calcaratus* were collected but not included in the final analysis due to a strict limitation to wandering spiders in the report, T. Bultman (unpubl. data)], 12 occurred in the 2005 sampling of the native site. Furthermore, none of the six species that occurred in the *Vinca* site, but not in the native site, were collected in the 1977 sampling; that is, none of the spider species found

Table 2 Jaccard's coefficient and Bray-Curtis index (in parentheses) of species similarity among native, *Vinca* and pre-*Vinca* sites

	Native	Pre- <i>Vinca</i>	<i>Vinca</i>
Native	—		
Pre- <i>Vinca</i>	.545 (.619)	—	
<i>Vinca</i>	.520 (.506)	.333 (.366)	—

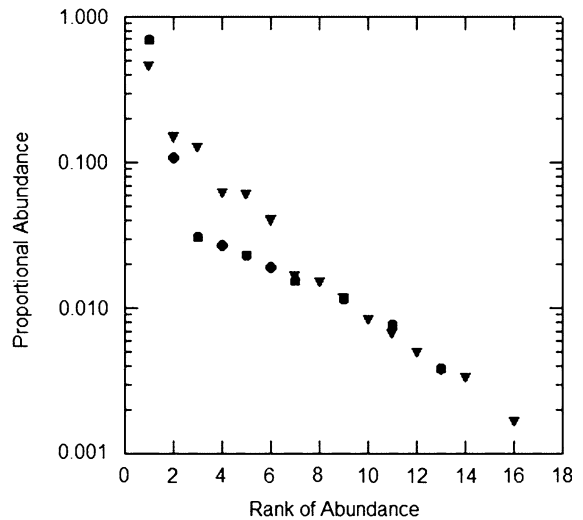


Fig. 3 Dominance diversity curves for cursorial spiders communities at native (triangles) and *Vinca* (circles) sites within a beech-maple forest in southwestern Michigan, USA

exclusively in *Vinca* were found in the forest in 1977. Of the 15 species in the pre-*Vinca* site, 60.0% also were collected at the *Vinca* site (compared to 68.4% species overlap between native and *Vinca* sites). Both Jaccard's coefficient and the Bray-Curtis index of species overlap showed the native and pre-*Vinca* samplings were more similar to one another than either was to the *Vinca* site (Table 2).

The proportion of individuals within guilds was also similar between the pre-*Vinca* and native samplings: 46.4% versus 59.8% for vagrant web builders; 34.4% versus 24.4% for running spiders; 18.9% versus 15.7% for sit and wait predators; and, 1.1% versus 0% for hunting spiders, respectively (Fig. 1). The pre-*Vinca* community had three species, which were quite abundant (*N. magna*, *Phrurotimpus alarius*, and *Phrurotimpus borealis*) while the native community had one overwhelming numerical dominant (*N. magna*—Table 1). This shift led to a decline in

species diversity and evenness from the pre-*Vinca* sampling to native site sampling (Table 1). Dominance diversity curves were relatively steep for native and pre-*Vinca* sampling periods (Fig. 3, Bultman et al. 1982)

Discussion

Invasion by *V. minor* resulted in a pronounced reduction in active density of cursorial spiders, reducing their number by 48.7%. Furthermore, considering only spider species native to the beech-maple forest, *V. minor* reduced their abundance by 86.9% (Table 1). The mode by which this reduction occurs is not known; we consider two possible mechanisms. Since *V. minor* is known to produce an assortment of alkaloids (Skakun et al. 1984), it is possible that bottom-up regulation of the forest floor food web reduces the abundance of predators, like spiders. However, the plants that *V. minor* replaces (seedlings of canopy trees and some herbs) are generally less dense than the thick mat that *V. minor* produces and the herbivorous arthropods that feed on native forest floor vegetation (as well as their predators) are likely not prey of ground dwelling spiders (Sanders and Platner 2007). Therefore, bottom-up regulation seems an unlikely explanation for reduced spider abundance, however we caution that we lack estimates of overall arthropod abundance in the native and *Vinca* sites. A more likely explanation is the modification *V. minor* makes to the physical features of the forest floor. Distinguishing between these hypotheses awaits further investigation.

The natural habitat of thick leaf litter, canopy seedlings and herbaceous plants is radically transformed by *V. minor* into a blanket of dense foliage. This creates a tangle of leaves and stems to which some spiders living in the litter of beech-maple forests may be ill adapted. Furthermore, abiotic conditions on the soil surface are changed by *V. minor*. Sunlight is greatly reduced as is accumulating leaf litter (T. Bultman, pers. obs.). It is well recognized that spiders are strongly affected by the physical features of their habitat (Bultman et al. 1982; Uetz 1991; Wise 1993). Web-building species require adequate web-attachment points and strictly cursorial species require a substrate over which they can efficiently forage. Changes in the physical structure

of the litter/soil microhabitat with the invasion of *V. minor* likely are a cause of the substantial reduction in activity-abundance of native spider species we observed. It is also possible that the *V. minor* ground cover reduced spider mobility (for reasons stated above) and that at least part of the reduction in activity-abundance we observed is due to reduced movement by individual spiders.

Interestingly, species richness did not differ between native and *Vinca* sites (Table 1). Invasion by *V. minor* was associated with the addition of six species that were not found in the native site. These additions were exactly offset by the loss of six native species at the *Vinca* site. Thirteen species occurred at both sites. While species richness was the same, analysis of species similarity between the two sites showed that the spider assemblages were quite distinct, with similarity index values near 0.50. Five of the six new species at the *Vinca* site were quite rare, but one, the lycosid *P. montanus*, was extremely common and made up over 70% of the individuals collected from the *Vinca* site. This wolf spider apparently is very well adapted to the new niche *V. minor* has provided in the forest. While it is not a normal constituent of the beech-maple forest, it is common along forest/pond and meadow/pond borders (Kaston 1981). Since there is no standing water near the *Vinca* site its occurrence there is rather surprising. It seems likely that the invasion by *V. minor* opened up an opportunity for this spider to invade the forest.

At the community level, invasion by *V. minor* also had pronounced effects on the spider fauna of the beech-maple forest floor. Species diversity and evenness were both lower at the *Vinca* site (Table 1). The change in species evenness is mirrored in the dominance diversity curves which show *V. minor* was associated with a community tending more toward a geometric series over the three most abundant species (Fig. 3). Furthermore, guild- and family-level changes occurred with the invasion of *V. minor* (Figs. 1 and 2), the most noticeable of which was the reduction in domination by vagrant web builders, particularly one species: *N. magna*. The activity-abundance of this species dropped from 274 in the native habitat to just nine at the *Vinca* site. Sit and wait predators and running spiders also decreased in relative (and actual) activity-abundance at the *Vinca* site. Invasion by *V. minor* dramatically altered the

community organization of ground dwelling spiders, transforming the vagrant web builder dominated-community into a lycosid-dominated one more typical of an old field or very early successional forest ecosystem (Bultman et al. 1982).

Importantly, the cursorial spider community at the study site prior to *Vinca* invasion (Bultman et al. 1982) was very similar to the community we found at the native site (Tables 1 and 2). Some changes in spider species presence/absence and composition occurred in the beech-maple forest over the 28-years period, but the similarity between the communities is striking. Further, the guild composition has also remained quite stable over the time period (see Results). Thus, it is likely that the differences we found in the cursorial spider community between the native and *Vinca* sites are a result of the invasion of the ground cover plant and not some other unmeasured difference between the two sampling sites.

In sum, invasion by a ground cover plant into a beech-maple forest not only alters recruitment of native saplings (Schulz and Thelen 2000, Darcy and Burkart 2002), but also has pronounced effects on the community organization and activity-abundance of an important group of predators in the detritus food web. The dramatic reductions in overall spider abundance and changes in guild structure and community organization that we found associated with invasion by *V. minor* into the forest likely have important impacts on ecosystem-level processes, like decomposition and mineralization. These potential affects await further investigation.

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