

Restoring Nutrient Capture in Forest Herbaceous Layers of the Midwest (Iowa)

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Much of the natural land cover in the American Midwest has been altered to support intensive agricultural production. One unintended consequence has been excessive nutrient and sediment pollution of waterways (Mitsch et al. 2001). Many remnant natural forests are located between fields and waterways, and restored riparian forest “buffers” have also been added in these landscape positions. These forest remnants and constructed buffers are ideally located to help decrease sediment and nutrient pollution to streams and rivers (e.g., Lee et al. 2003).

However, agriculture (primarily cattle grazing) and other human activities in many remnant riparian forests in the region have led to a dramatic decrease in native herbaceous layer diversity. Although such sites typically can support such vegetation, many native herbaceous perennials are sensitive to grazing, and limited dispersal capacity makes their recovery slow after disturbance. In particular, shade-tolerant spring-growing perennials are often rare or absent in disturbed remnant forests (Mabry 2002), and many newly constructed forested buffers do not include a perennial herbaceous component. These early-growing perennial plants are functionally important in capturing and storing nutrients at a time of high potential loss when woody plants are still dormant (Muller and Bormann 1976, Blank et al. 1980). Individual species, such as spring beauty (*claytonia virginica*) and trout lily (*Erythronium americanum*), have a high capacity for nutrient storage (Anderson and Eickmeier 2000, Muller and Bormann 1976), as have more diverse groups of spring herbs (Blank et al. 1980, Peterson and Rolfe 1982). Thus through conversion of forest to agricultural land and degradation of remnants, the capacity of forests in the Midwest to function in nutrient interception has been diminished.

In a recent study, we compared plant species composition and nutrient capture between high-quality, preserved forest remnants (hereafter referred to as intact forests) and forests that had experienced grazing (disturbed forests) (Mabry et al. 2008). These central hardwood forests did not differ in terms of soil nutrients, and neither the intact nor disturbed sites had been heavily invaded by non-native perennials or shrubs. We found that the intact forests displayed higher levels of nitrogen and phosphorus capture in spring than disturbed forests. We could attribute these differences to greater biomass production of spring-growing native perennials in the intact herbaceous plant communities, characterized by species such as Virginia waterleaf (*Hydrophyllum virginianum*), spring beauty, trout lily, and wild ginger (*asarum canadense*) (Mabry et al. 2008).

One implication of our previous research is that restoring herbaceous species to forests may enhance nutrient capture and storage. In this study, a follow-up to our previous work, we seek to

identify a set of key spring-growing herbaceous species to restore to degraded forests or recently constructed riparian forest buffer areas in order to improve nutrient retention. We chose four spring-growing species—wild ginger, Virginia waterleaf, Virginia bluebells (*Mertensia virginica*), and bristly buttercup (*Ranunculus hispidus*)— that often grow in intact forests but are usually rare or absent in disturbed forests. We also based our choice on the capacity of these species for high biomass production and great potential for vegetative spread, and the feasibility for restoration either by seed or transplant. The objective of this study was to assess the capacity for nutrient capture by these individual spring-growing species. We predicted that these species, alone or in combination, could equal or exceed the nutrient retention capacity we have previously documented for the spring herbaceous community of a set of intact forests (Mabry et al. 2008).

To facilitate comparison between the current study of key species and our earlier study of intact forests, we followed identical field, sampling, and analysis protocols. In our earlier study, we excavated plant material from 0.25 m² quadrats in intact and disturbed forests in central Iowa (Mabry et al. 2008). We randomly selected a subset of nine of these for use in the comparison, eliminating a restored woodland (this site was a “superperformer” in terms of nutrient capture and not typical of native woodlands). We then identified three sites in central Iowa where our selected key species were present in large, dense colonies, and harvested three 0.25 m² quadrats per site for a total of nine quadrats per species. Owing to the patchy growth habit of these species, we located harvest quadrats nonrandomly in areas where each species was dominant. We harvested during peak spring growth in late April to mid-May. We computed summary statistics (means, standard errors, and 95% confidence intervals) using JMP (vers. 7.1, SAS Institute, Cary NC).

We found high levels of biomass both above- and below- ground for each of the four species, ranging from 10 to 21 g per 0.25 m² aboveground and from nearly 6 to 34 g per 0.25 m² belowground (Table 1). Bristly buttercup, which has smaller leaves and a sparser growing habit, produced the least and wild ginger the most aboveground biomass. Each species occurring alone produced aboveground biomass quantities that were similar to or exceeded the diverse intact understory plots and were from three to seven times higher than the disturbed understory plots. Belowground biomass production for three of the selected species (the exception again was bristly buttercup) also was similar to or exceeded the intact plots and ranged from about three to eight times that of disturbed understory plots. Total biomass for all of the individual species plots followed a similar pattern (Table 1). At a landscape scale, these biomass differences translated into at least 500 kg/ha more production for wild ginger, Virginia waterleaf, and Virginia bluebells compared to intact understory plots and at least 1,200 kg/ha more production compared to disturbed plots (Figure 1a).

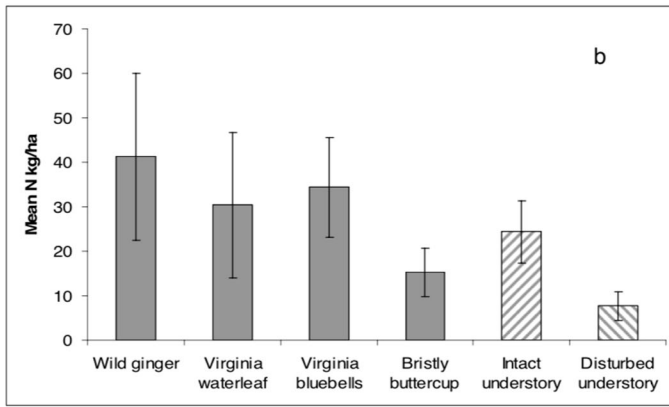
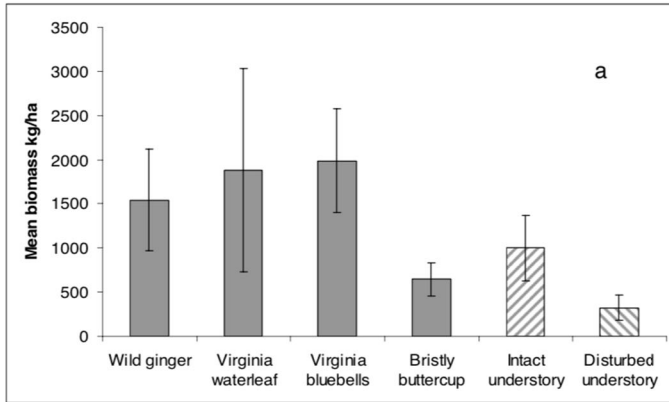


Figure 1. Comparison of individual native perennial herbaceous species and understory plant communities in intact and disturbed riparian forest in central Iowa, USA: a) mean (\pm 95% CI) biomass; and b) mean (\pm 95% CI) tissue nitrogen content ($n = 9$). Estimates include above- and belowground plant parts. Understory community data are from Mabry et al. 2008.

Similarly, at the landscape scale, our estimates for total nitrogen capture (kg/ha) are greater for each of the individual species than for the disturbed understory plots and comparable to that of intact understory plots (Figure 1b). Our results corroborate earlier findings that nitrogen capture is largely driven by biomass production (Mabry et al. 2008), even though we detected some variation in the percent nitrogen in the plant tissue (Table 1). Our earlier study suggested that leaf-tissue nutrient concentrations were not an important component of nutrient retention. However, the current study suggests that this may not hold for all species, because even though bristly buttercup produced less biomass than other species we examined, relatively high tissue nitrogen concentrations suggest greater potential for nitrogen capture than indicated by biomass alone.

Table 1. Mean biomass and tissue nitrogen content for single species and understory community plots at harvest sites in central Iowa, USA. Understory community data (shaded rows) from Mabry et al. 2008.

Species	Biomass (g per 0.25 m ²)			% N content	
	Aboveground	Belowground	Total	Aboveground	Belowground
Wild ginger (<i>Asarum canadense</i>)	21.08	17.51	38.59	3.36	1.74
Virginia waterleaf (<i>Hydrophyllum virginianum</i>)	12.90	34.07	46.97	2.66	1.32
Virginia bluebells (<i>Mertensia virginica</i>)	16.95	32.70	49.65	3.27	0.90
Bristly buttercup (<i>Ranunculus hispidus</i>)	10.36	5.77	16.13	2.79	1.60
Intact understory	11.39	13.61	25.00	3.52	1.99
Disturbed understory	3.21	4.83	8.04	3.34	2.01

Total average biomass produced on individual species plots in this study are higher than previous studies have shown for other spring herbs such as spring beauty (Eickmeier and Schussler 1993), cut-leaf toothwort (*cardamine concatenata*), and squirrel corn (*Dicentra canadensis*) (Blank et al. 1980). This is not surprising, as we purposefully selected species that we expected to produce more bio- mass than typical spring herbs and that could be targeted for restoration of nutrient-storage function. Our results demonstrate that certain functionally important species can equal or exceed the capacity of an intact, diverse herbaceous layer for biomass production and nutrient capture. In particular, restoration or addition of these key species (wild ginger, Virginia waterleaf, Virginia bluebells, and bristly buttercup) to degraded or newly constructed riparian hardwood forests of the Midwest could increase nutrient storage during spring, a critical time for potential nutrient loss. We could maximize nutrient capture for one of our most troublesome pollutants, nitrogen, by maximizing biomass production in spring and potentially see added benefits from plants that persist into the growing season, for example, Virginia waterleaf and wild ginger.

Many forest species, particularly spring-growing species, are difficult to restore because they have one or more of the following characteristics: large seeds with low seed production, seeds that do not tolerate dry storage, exacting germination requirements, or slow growth (e.g., Mottl et al. 2006). However, many typical woodland perennials, such as wild ginger and Virginia waterleaf, can be successfully transplanted and, once present, spread relatively rapidly to form dense colonies (Mottl et al. 2006). Next steps in this research should include identification of methods for seed and nursery propagation that result in sufficient quantities of plant material to allow landscape-scale restoration at a feasible cost.

While structural and biological diversity of native forests, including the herbaceous layer, should be the ultimate goal of most restoration efforts, from a practical standpoint it is also important to identify cost-effective methods for restoring function, if only in critical areas. Based on our results, addition of a limited number of species with good establishment potential and high functional capacity shows great potential as one tool to mitigate nutrient impacts in highly modified landscapes. This is especially important in the upper Midwest where the negative impacts of agricultural intensification on water quality are particularly severe.

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