

Impact of Native Plants on Bird and Butterfly Biodiversity in Suburban Landscapes

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Abstract: *Managed landscapes in which non-native ornamental plants are favored over native vegetation now dominate the United States, particularly east of the Mississippi River. We measured how landscaping with native plants affects the avian and lepidopteran communities on 6 pairs of suburban properties in southeastern Pennsylvania. One property in each pair was landscaped entirely with native plants and the other exhibited a more conventional suburban mixture of plants—a native canopy with non-native groundcover and shrubs. Vegetation sampling confirmed that total plant cover and plant diversity did not differ between treatments, but non-native plant cover was greater on the conventional sites and native plant cover was greater on the native sites. Several avian (abundance, species richness, biomass, and breeding-bird abundance) and larval lepidopteran (abundance and species richness) community parameters were measured from June 2006 to August 2006. Native properties supported significantly more caterpillars and caterpillar species and significantly greater bird abundance, diversity, species richness, biomass, and breeding pairs of native species. Of particular importance is that bird species of regional conservation concern were 8 times more abundant and significantly more diverse on native properties. In our study area, native landscaping positively influenced the avian and lepidopteran carrying capacity of suburbia and provided a mechanism for reducing biodiversity losses in human-dominated landscapes.*

Keywords: biodiversity, birds, Lepidoptera, managed ecosystems, native plants, non-native plants, suburban landscape

Impacto de Plantas Nativas sobre la Biodiversidad de Aves y Mariposas en Paisajes Suburbanos

Resumen: *Los paisajes bajo manejo en los que las plantas ornamentales no nativas son favorecidas en lugar de la vegetación nativa son dominantes en los Estados Unidos, particularmente al este del Río Mississippi. Medimos el efecto del ajardinado con plantas nativas sobre las comunidades de aves y lepidópteros en seis pares de propiedades suburbanas en el sureste de Pennsylvania. Una propiedad en cada par estaba ajardinada con plantas nativas completamente y la otra presentaba una mezcla suburbana de plantas más convencional – un dosel nativo con hierbas y arbustos no nativos. El muestreo de la vegetación confirmó que la cobertura total de plantas era mayor en los sitios convencionales y que la cobertura de plantas nativas era mayor en los sitios nativos. Medimos varios parámetros de la comunidad de aves (abundancia, riqueza de especies, biomasa y abundancia de aves reproductoras) y de lepidópteros larvales (abundancia y riqueza de especies) de junio 2006 a agosto 2006. Las propiedades nativas sustentaron un número significativamente mayor de orugas y de especies de orugas, así como una abundancia, diversidad, riqueza de especies, biomasa de aves y parejas reproductoras de especies nativas significativamente mayores. Es de particular importancia que las especies de aves de interés de conservación regional fueron 8 veces más abundantes y significativamente más diversas en las propiedades nativas. En nuestra área de estudio, el ajardinado nativo influyó positivamente sobre la capacidad de carga de aves y de lepidópteros de los suburbios y proporcionó un mecanismo para reducir las pérdidas de biodiversidad en paisajes dominados por humanos.*

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Paper submitted October 1, 2007; revised manuscript accepted June 16, 2008.

Palabras Clave: aves, biodiversidad, ecosistemas bajo manejo, Lepidóptera, plantas nativas, paisaje suburbano, plantas no nativas

Introduction

Invasive plant species with origins in Asia, Europe, or South America have received considerable attention in recent years because of their ecological impact on North American plant and animal communities (Pimentel et al. 2005). In contrast, non-native plants popular in suburban landscapes have not been considered a threat to biodiversity because most of them are ornamental and lack invasive traits. Regardless of their dispersal abilities, non-native ornamentals, favored by landscapers and homeowners, now dominate the first trophic level in millions of hectares of North America. How the large-scale replacement of native vegetation with non-native plants in managed ecosystems affects members of higher trophic levels has yet to be determined.

Of particular concern are insect herbivores and the many species of invertebrate and vertebrate insectivores that eat them (Tallamy 2004). Theory (Ehrlich & Raven 1964) backed by decades of empirical evidence (Rosenthal & Janzen 1979; Weiss & Berenbaum 1988) predicts that up to 90% (Bernays & Graham 1988) of all species of insect herbivores can successfully reproduce only on plant lineages with which they have shared an evolutionary history. With rare exceptions, insects cannot adapt rapidly to evolutionarily novel plants (Southwood et al. 1982) because developing specialized physiological adaptations to detoxify, sequester, and excrete the noxious phytochemical defenses of one host typically does not predispose an insect lineage to breaking down the defenses of other plants. Thus, landscapes dominated by non-native plants, whether unwanted invasives or desirable ornamentals, are unlikely to support the same diversity and biomass of insect herbivores as landscapes dominated by native host plants. Moreover, if the presence of non-native plants compromises insect biomass, it follows that populations of insectivores such as birds will also be compromised. Given that 96% of all terrestrial birds in North America rear their young in part or entirely on insects (Dickinson 1999), large-scale reductions in available insect biomass may have serious conservation implications that could be mitigated with changes in landscape practices.

We quantified how simple changes in the paradigm that has dominated suburban landscaping for over a century affect biodiversity in the Piedmont region of the eastern deciduous forest (U.S.A.). Controlling for total plant structure and cover, we compared biodiversity between suburban properties landscaped primarily with native ornamental plants with nearby properties landscaped with

a conventional mix of native and non-native ornamentals. We used lepidopteran larvae as a surrogate for the insect herbivores that support much of the terrestrial food web and breeding birds as a surrogate for insectivore diversity. We predicted that lepidopteran larval abundance would correlate positively with the extent of native vegetation on each property. Given greater insect abundance on native versus non-native plant species, we also predicted that bird species abundance and richness would be greater on suburban properties landscaped with native plants.

Methods

We conducted this study in a landscape that is typical of suburban areas in the southeastern Pennsylvania Piedmont. We selected 6 pairs of properties within this region that ranged in size from 0.13 to 5.26 ha. One site-pair member was landscaped conventionally, with large mowed lawns of cool-season Eurasian grasses, Asian shrubs and understory trees, and a native canopy. The other was landscaped entirely with native ornamentals at all vegetative levels (canopy, understory, shrubs, and grasses). For each pair of sites, the conventional site was within 1.6 km of the native site, but the 2 sites were not adjacent to avoid confusion from bird-use overlap during data collection. During site selection, we attempted to match pairs so they would not differ in area, vegetative structure and cover, or surrounding landscape features such as bordering woodlands and streams, building cover, bird nest boxes, and bird feeders.

We used line-intercept sampling to estimate vegetation cover (native vs. non-native), biomass, and structure as a measure of the overall composition of vegetation cover (Krebs 1999). We compared vegetation structure between site pairs by measuring the total percentage of plant cover at 4 height strata (5 cm, 1 m, 4 m, >15 m). We estimated percent cover of each plant species along 4 transects originating from, and equally spaced along, the longest side of each property by recording the length of each transect intercepted by each species at the 4 height strata. Areas of the transect with a heterogeneous cover of multiple species (e.g., a meadow or mowed lawn) were divided into "communities" in which the cover and plant species composition remained relatively consistent. We categorized each species in these communities as a dominant, average, or rare member of that community and then assigned that species a value for percent cover of

the transect line based on its dominance category and number of species present in that community. We classified plants as native or non-native on the basis of range and status maps from the PLANTS database (USDA 2007). We defined non-native as not having shared an evolutionary history with the plants and animals of the mid-Atlantic Piedmont.

From 11 August until 8 September 2006, we used a total search approach (Wagner 2005) to quantify Lepidoptera larvae at 3 evenly spaced intervals along each of the 4 vegetation transects on a property. At each sample point along the transect, on days with no rain, we recorded all lepidopteran larvae on all twigs and vegetation within reach and inside a circle defining a vertical cylinder with a 0.5-m radius between 09:00 and 14:00. We sampled lepidopteran larvae at one site pair per day, alternating whether we searched the native or conventional property first and identified each individual to species or morphospecies. Because Lepidoptera abundance is a function of the abundance and quality of available host plants, we sampled larvae in a way that captured the abundance and dispersion of plants supporting larvae on each pair of properties. Thus, rather than attempting to record all the species occurring on each property, we created a relative index of Lepidoptera abundance and diversity that we could use to compare the Lepidoptera productivity of each member of a property pair.

We estimated breeding-bird species richness and diversity with 25-m fixed-radius point counts (Donnelly & Marzluff 2004). Sampling points were selected with orthophotos to maximize the number of points on each property while maintaining a 25-m buffer between adjacent circles to minimize double counting. The number of avian sampling points was consistent within site pairs. Avian data were collected between 05:00 and 07:00 from 7 June through 20 July 2006. We recorded all birds seen or heard within the 25-m radius plot for a 5-minute interval. Birds flying above the canopy within the radius were not included because we could not determine whether they were using the habitat. Weather permitting, we sampled a pair of properties per morning and alternated the treatment that was sampled first for 3 total sample dates for each pair of sites. We also noted birds actively breeding on a site by locating a nest, observing transport of nesting material or food, or observing fledglings.

We estimated avian abundance at each site by summing the maximum number of individuals detected across the 3 point counts for each species and dividing it by the number of points sampled on a property. All estimates and comparisons were made with the site as the sampling unit ($n = 6$). We compared avian species richness between pairs for all native species of breeding birds and for species of high conservation priority. We removed 2 non-native species from the breeding-bird analysis. These were nesting House Sparrows (*Passer domesticus*) and House Finches (*Carpodacus mexicanus*) with origins in

England and California, respectively (Ehrlich et al. 1988; Hill 1993). We based conservation priority on Rich et al. (2004). For the study area (physiographic area 10), the birds of conservation concern (BCC) were the Great Blue Heron (*Ardea herodias*), Veery (*Catharus fuscens*), Wood Thrush (*Hylocichla mustelina*), Scarlet Tanager (*Piranga olivacea*), and Eastern Towhee (*Pipilo erythrophthalmus*). Avian biomass was estimated by multiplying abundance by average species weight (Sibley 2000). Birds were assigned to either insectivorous or omnivorous breeding-season trophic guilds so we could compare guild species richness and abundance between native and conventionally landscaped properties (Ehrlich et al. 1988).

We used Simpson's (1949) diversity index to estimate plant and avian diversity. We used Spearman's correlation to determine the relationships between native and non-native plant cover and lepidopteran and avian abundance. We used paired t tests ($\alpha = 0.05$) to compare native and conventional properties for all variables. We report all results as mean with standard error. Supplementary appendices of avian, botanic, and lepidopteran data are available from D.W.T.

Results

Site size did not differ between native (2.32 ha [0.73]) and conventionally (2.27 ha [0.71]) landscaped sites ($t = 0.139$, $p = 0.895$). Site pairs were also matched in at least 5 of the other 6 characteristics controlled for in the selection process (birdseed provisioning, bird boxes, number of wooded borders, presence of a stream border, building cover, and encompassed wood). One site matched all characteristics, 2 sites had a mismatched character that would seem to enhance bird populations on the conventional site (1 bird box, 1 birdseed provisioning), and 3 sites had such a character on the native site (2 bird box, 1 stream border).

Percent total vegetation cover did not differ between native (49.3% [3.7]) and conventionally (44.9% [3.3]) landscaped sites ($t = 1.730$, $p = 0.144$). Native plant cover was 2.4 times greater on the native properties (43.7% [3.3]) than on conventional properties (17.9% [4.1], $t = 7.956$, $p < 0.001$), whereas non-native plant cover was 4.3 times greater on conventional properties (26.2% [3.3]) than on native properties (6.1% [2.5], $t = 21.235$, $p < 0.001$). These differences occurred exclusively in the 5-cm and 1-m height strata; properties did not differ in native and non-native plant cover in the 4-m or > 15-m strata (Table 1). In the 5-cm stratum, native properties had 6 times more native plant cover than conventional properties, and conventional sites had 3.5 times more cover of non-native plants than native sites (Table 1). In the 1-m stratum, native sites had 4 times more native cover

Table 1. Comparison of mean percent cover of vegetation at 4 height strata on study sites landscaped with predominantly native plants and sites landscaped with a combination of non-native ornamentals and natives (conventional).

Height of vegetation transect	Category of cover	Native (SE)	Conventional (SE)	t	p
5 cm	total	80.2 (8.8)	78.4 (8.0)	0.328	0.756
	native	59.2 (11.5)	10.3 (4.7)	5.419	0.003
	non-native	19.9 (8.9)	66.6 (8.3)	-4.484	0.006
1.0 m	total	33.4 (3.8)	21.3 (8.9)	1.641	0.162
	native	31.4 (3.8)	7.5 (4.6)	5.498	0.003
	non-native	2.0 (1.5)	12.6 (6.4)	-2.276	0.072
4.0 m	total	35.0 (6.5)	43.3 (10.0)	-0.974	0.375
	native	32.6 (5.5)	23.4 (8.4)	1.338	0.239
	non-native	9.6 (8.1)	25.7 (9.6)	-1.795	0.133
>15 m	total	48.3 (10.6)	36.5 (9.8)	0.971	0.376
	native	48.0 (10.5)	30.5 (10.8)	1.261	0.263
	non-native	0.3 (0.3)	5.8 (3.8)	-1.543	0.184

than conventional sites (Table 1). Plant species richness was higher on native sites (58.0 [13.3] species/site) than conventional sites (31.2 [6.9] species/site, $t = 3.806$, $p = 0.013$), but Simpson's diversity index did not differ between native (0.91 [0.03]) and conventionally landscaped sites (0.82 [0.06], $t = 2.364$, $p = 0.064$). Native plant diversity was positively correlated with lepidopteran abundance ($r = 0.836$, $p < 0.001$) and avian abundance ($r = 0.589$, $p = 0.044$). Non-native plant diversity was negatively correlated with lepidopteran abundance ($r = -0.838$, $p < 0.001$) and avian abundance ($r = -0.602$, $p = 0.038$).

Lepidoptera abundance was 4 times greater on native sites (12.7 [2.1] larvae/site) than on conventional sites (3.0 [1.4] larvae/site, $t = 8.665$, $p < 0.001$), and lepidopteran species richness was 3 times greater on native sites (6.8 [1.1] species/site) than on conventional sites (1.8 [0.8] species/site, $t = 7.906$, $p < 0.001$).

We noted 46 bird species among all the sites. Avian metrics (abundance, species richness, biomass, diversity, and native nesting pairs) were all significantly greater on

properties landscaped with native species than on those with conventional landscaping (Table 2). Abundance and richness of avian species of conservation concern were also significantly greater on native properties. The abundance and richness of avian insectivores ($n = 33$ species), but not omnivores ($n = 13$ species), were significantly greater on native sites (Table 2).

Discussion

Diversity indices of both lepidopteran larvae and breeding birds responded positively to a greater percentage of native grasses, forbs, and shrubs in residential landscapes. Avian abundance, diversity, richness, and biomass (particularly bird species of conservation concern) were all greater on native properties. Native nesting birds that are mostly dependent on insect populations to feed their young (Dickinson 1999) were more abundant on native properties. Lepidoptera abundance and diversity were also higher on native properties, suggesting that food

Table 2. Comparison of bird-community metrics recorded on properties landscaped primarily with native plants versus properties landscaped with a combination of non-native ornamentals and natives (conventional).

Metric	Native (SE)	Conventional (SE)	t	p
Abundance (individuals/point)	16.86 (1.81)	10.96 (1.02)	7.201	<0.001
Richness (species/site)	18.83 (3.09)	11.33 (2.38)	8.859	<0.001
Biomass (g/point)	956.28 (94.97)	636.94 (70.12)	3.238	0.023
Simpson's diversity index (0-1)	0.92 (0.01)	0.840 (0.03)	3.053	0.028
All breeding birds (pairs/point)	1.63 (0.17)	0.96 (0.26)	2.457	0.057
Breeding birds w/o non-native species (pairs/point)	1.63 (0.17)	0.75 (0.14)	3.656	0.015
BCC* abundance (/point)	1.13 (0.34)	0.13 (0.14)	3.098	0.027
BCC* richness (/site)	1.67 (0.54)	0.17 (0.18)	3.503	0.017
Insectivore abundance (/point)	13.79 (1.76)	7.13 (0.88)	4.434	0.007
Omnivore abundance (/point)	3.07 (0.47)	3.83 (1.06)	-0.868	0.425
Insectivore richness (/site)	14.67 (2.67)	7.83 (1.906)	5.590	0.003
Omnivore richness (/site)	4.167 (0.44)	3.50 (0.84)	1.348	0.235

*Birds of conservation concern for study region as determined on the basis of Rich et al. (2004).

availability might account for the differences detected in the bird communities between native and conventionally landscaped sites. Beissinger and Osborne (1982) demonstrated a similar pattern in bird community response to urbanization in Ohio and alluded to the effect of vegetation type (non-native vs. native) as a potential explanatory factor. In addition, the effect of food limitation on fitness might be even more pronounced when adults of a species also depend for their own nutrition on insect abundance. This was the pattern we observed in our study; trophic guild analyses revealed that the bird species driving the differences between sites were those that specialize on insects during the breeding season.

Plant species richness was higher on native properties but Simpson's Index, a diversity index that incorporates relative abundance, did not reveal a difference between native and conventionally landscaped sites. Although these results suggest that the evolutionary origins of the plants is the source of differences in avian and lepidopteran abundance and diversity in our study, a field experiment rigidly controlling for plant richness and diversity would more clearly isolate these variables. Nevertheless, conventional landscaping typically creates relatively homogenous habitats. Because we attempted to control for plant diversity, our 6 conventional sites were more diverse than typical suburban landscapes. Thus, we consider our results conservative because of the similarities in native canopy and understory trees between our native and conventional properties. Our paired properties differed only in the proportion of shrub and groundcover that consisted of native plants. Greater differences in biodiversity are expected in comparisons between properties landscaped with natives and more typical suburban landscapes in which non-native trees such as Norway maple (*Acer platanoides*), Norway spruce (*Picea abies*), Bradford pear (*Pyrus calleryana*), and goldenrain tree (*Koelreuteria paniculata*) have replaced native canopy trees.

Our results followed our prediction that enhancing the biomass and diversity of native plants would increase the diversity and abundance of insect herbivores and thus create a greater resource base for important insectivores such as birds (Tallamy 2004). It is well documented that most bird species are food limited (Marra et al. 1998; Nagy & Holmes 2005; Granbom & Smith 2006). What is becoming more apparent is that by reducing insect food availability, non-native plants are indirectly reducing bird abundance in natural systems (Wilson & Belcher 1989; Lloyd & Martin 2005; Flanders et al. 2006) and, counter to recent claims (Burdick 2005), are not "seamlessly" entering North American ecosystems without ill effects. Our results suggest that the negative relationship between non-native plant abundance and bird community integrity is apparent in managed ecosystems as well, regardless of whether the non-native species are invasive. By demonstrating the connection between native plants and suburban biodiversity, we provide evidence

that the landscaping choices of homeowners affect populations of both birds and the insect food they require, thus empowering homeowners, landscapers, and policy makers to raise (or lower) local carrying capacities by plant choice alone.

Acknowledgments

We thank Larry Weaner Landscapes for providing access to willing property owners; cooperating landowners who allowed us to invade their yards and privacy during the course of the study; T. D. Pizzolato and J. J. Frett for help with plant taxonomy; and the Undergraduate Research Program at the University of Delaware for financial support. This manuscript benefited from the thoughtful comments of 4 anonymous reviewers.

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