Native Meadow Trial at the Hudson Valley Farm Hub

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February 2019

Introduction

The Hudson Valley Farm Hub is a non-profit, organic farm located on 1,200 acres of prime farmland in the floodplain of the Esopus Creek, between the Catskills and the Hudson River. It strives to contribute to a resilient food system for the Hudson Valley and is committed to strengthening the synergies between farming and wild nature. The Farm Hub is a production farm that also serves as a resource for education, demonstration, and research.

One area of research is the establishment and monitoring of on-farm habitats to support beneficial invertebrates and other wildlife. In 2017, we established a native meadow trial on former cornfields, which had been taken out of tillage because of their exposure to infrequent but severe flooding.

Objectives of the Native Meadow Trial

Our overall objective for the native meadow trial is to understand what seed mixes and management regimes can produce good herbaceous habitat for beneficial insects and other wildlife at the Farm Hub. Specifically, we hope to learn and document the following:

- What does it take (in terms of equipment, labor, and cost of seeds) to establish permanent meadows composed mostly of native grasses and wildflowers on former cornfields? Is it possible without the use of herbicides and with techniques that are potentially practical to other farmers?
- Which plant species seem most suitable as components of permanent meadows here at the Farm Hub and so, perhaps, elsewhere in the region?
- Which invertebrates are attracted to the experimental plots of the native meadow trial? What is the balance between beneficial insects and pests?
- What role might these native meadows play for birds?
- How do soil conditions evolve in the native meadow trial plots compared to neighboring hayfields and tilled soil?

The native meadow trial plots are intended to serve as well-documented demonstration areas and inspiration for other farmers. They will also help inform future management decisions at the Farm Hub itself, as it explores opportunities for conservation biological control, pollinator conservation, and options for productive permanent cover of flood-prone fields.

Methods

The Native Meadow Trial consists of three rectangular trial areas of 320 x 200 feet (NMT1, NMT2, and NMT3; Figure 1), each of which has been subdivided into three experimental plots (A, B, C) of 100 x 200 feet, separated by 10 foot wide strips of mowed grass/clover.

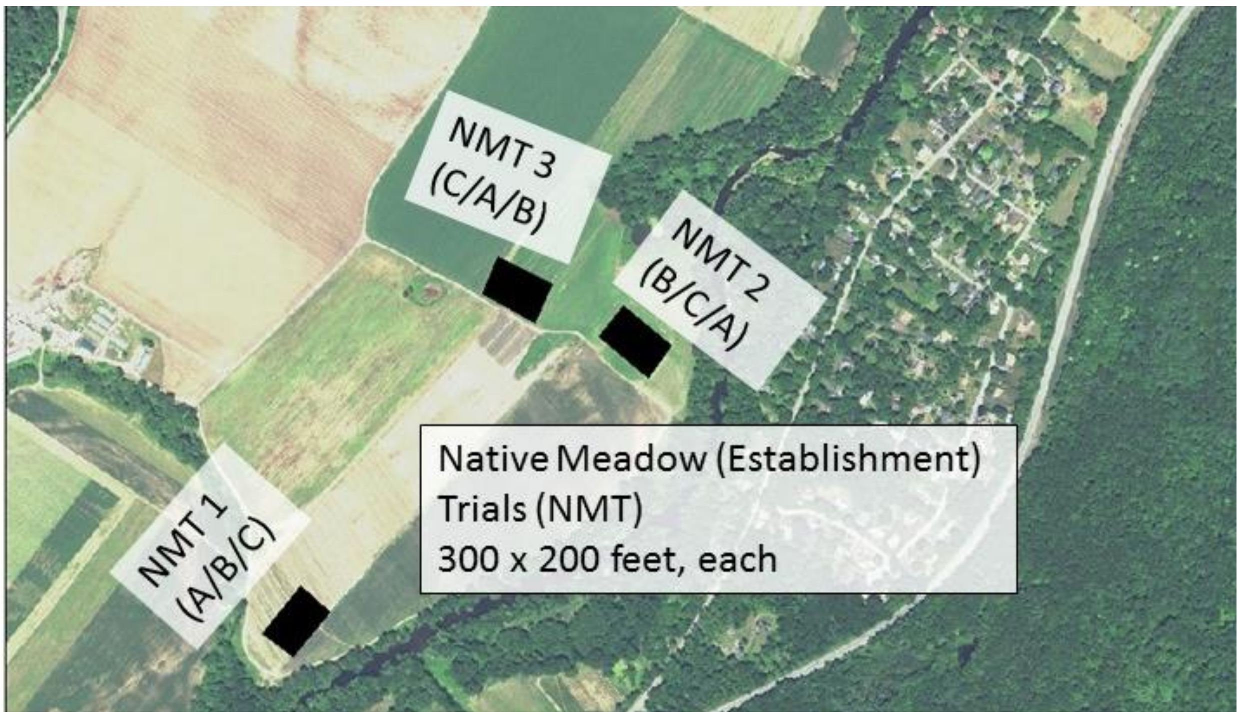


Figure 1: Map of Native Meadow Trial Areas at the Hudson Valley Farm Hub

Soil Types: The trial areas were located on different soil types. NMT1 is on Tioga fine sandy loam, NMT2 on Suncook loamy fine sand, and NMT3 on Unadilla silt loam. The soil characteristics are described in more detail in the results section below.

Crop History: All three trial areas were planted in Sweet Corn (preceded and followed by Rye) in 2013. In 2014, they all had a cover crop of Crimson Clover. In 2015, NMT1 was planted in mixed vegetables and NMT2&3 were in Wheat, all followed by Rye. In 2016, all three trial areas were planted in Rye, followed by Oat—in preparation for the seeding with native meadow seed mixes the following year.

Site Preparation: The decision to dedicate these particular areas to the native meadow trial was only made in the summer of 2016, when they were all in Rye. We decided to plan for a spring 2017 seeding, realizing that this would not allow for the recommended year-long site preparation. The trial areas were seeded with Oat in fall 2016, which was expected to winter-kill and leave bare soil for seeding the following spring. Although the Oat was winter-killed, the Rye volunteered in most of the experimental areas in early spring 2017. Therefore, the experimental areas were harrowed three times in the spring of 2017 with a Perfecta II Harrow with S-tines equipped with duck feet in order to uproot the rye and to prepare a weed-free seedbed for the native meadow mixes. Each harrowing pass over the entire 4.5 acre trial area took 2 hours. According to Jean-Paul Courtens (then one of the farmers at the Farm Hub), disking would have accomplished the same; however a Perfecta Harrow with points (rather than duck feet) would not have been effective at uprooting the Rye.

Seed Mixes and Seeding: With the help of Kelly Gill (Xerces Society), we created two customized seed mixes for this trial. Meadow Mix A (see Table 2 and Figure 2) is an ideal (but expensive) pollinator mix, rich in wildflowers native to North America, most of them native to the Northeast (including 22 species which should provide ample flower resources to pollinators throughout the seasons) and with one species of native bunch grass (Little Bluestem). The cheaper Meadow Mix B (see Table 3 and Figure 3) has a variety of native bunch grasses, but also contains six native wildflowers, which likewise were selected to provide floral resources throughout the seasons. The seeds were sourced from three different suppliers, as indicated in Tables 2 and 3. Please also refer to these tables for scientific names of the plant species referred to in the text by common names. In addition to the perennial species listed as “official” components of the seed mixes, seeds from annual Blanketflower (*Gaillardia* sp.) and Phacelia (*Phacelia tanacetifolia*), which had been left over from annual insectary seedings elsewhere on the farm, were added to both seed mixes (approximately 1 lb of each species to each seed mix).

On May 19, 2017, we used a Great Plains No-till Seeder to seed experimental plots A and B in each of the three trial areas with Meadow Mix A and Meadow Mix B, respectively. For unknown reasons, we did not quite accomplish the recommended seeding rates, and seeds were left over after the first pass of the seeder. To correct this, the leftover seeds were broadcast by hand on May 25th (before the next rain, to maximize soil seed contact and minimize the danger of the seeds getting blown away by the wind) to approximate the recommended seeding rates. Seeds of each species in the seed mixes were seeded on May 19th into pots in the greenhouse to serve as a reference. This enabled us to photographically document seedling morphology and to monitor seed germination, both in the greenhouse and in the field.

Experimental plots C in each of the three trial areas were left fallow as a control and allowed to develop a plant community from the seed bank in the soil and from naturally dispersed seeds. These were cut and weeded on the same schedule as the seeded trial areas.

*Table 1: Species list for Seed Mix A, which is rich in wild flowers. Seeds from annual Blanketflower (*Gaillardia *sp.) and Phacelia (*Phacelia tanacetifolia*) were added to this mix, approximately 1 lb each.*

Native Meadow Mix A				
Common Name	Scientific Name	Percent of mix by volume (seed/ft2)	Final Mix Total pounds (lb) for 1.5 acres	Supplier
Blackeyed Susan	Rudbeckia hirta	6.5%	0.19	Ernst Seeds
Browneyed Susan	Rudbeckia triloba	2.2%	0.18	Ernst Seeds
Butterfly Milkweed	Asclepias tuberosa	1.1%	0.73	Ernst Seeds
Common Milkweed	Asclepias syriaca	1.1%	0.73	Ernst Seeds
Dense Blazingstar	Liatris spicata	1.1%	0.51	Ernst Seeds
Early Goldenrod	Solidago juncea	3.2%	0.06	Ernst Seeds
Joe Pye Weed	Eupatorium purpureum	1.0%	0.07	Prairie Moon
Lance Leaved Coreopsis	Coreopsis lanceolata	8.6%	1.84	Ernst Seeds
Lavender Hyssop	Agastache foeniculum	8.6%	0.27	Ernst Seeds
Little Bluestem	Schizachyrium scoparium	19.4%	4.59	Ernst Seeds
Mistflower	Eupatorium coelestinum	6.5%	0.20	Ernst Seeds
Narrowleaf Mountainmint	Pycnanthemum tenuifolium	3.8%	0.03	Prairie Moon
New England Aster	Aster novae-angliae	2.1%	0.09	Ernst Seeds
Ohio Spiderwort	Tradescantia ohiensis	2.2%	0.81	Prairie Nursery
Partridge Pea	Chamaecrista fasciculata	2.2%	1.57	Ernst Seeds
Purple Coneflower	Echinacea purpurea	4.3%	1.76	Ernst Seeds
Purple Prairie Clover	Dalea purpurea	2.2%	1.27	Ernst Seeds
Roundhead Lespedeza	Lespedeza capitata	1.1%	0.19	Prairie Moon
Showy Goldenrod	Solidago speciosa	2.3%	0.08	Ernst Seeds
Slender Lespedeza (added)	Lespedeza virginiana	2.1%	1.27	Ernst Seeds
Smooth Blue Aster	Aster laevis	2.1%	0.10	Ernst Seeds
Tall White Beardtongue	Penstemon digitalis	9.7%	0.25	Pinelands Nursery
Wild Bergamot	Monarda fistulosa	6.7%	0.25	Pinelands Nursery
	TOTALS:	100.0%	17.04 lbs	

*Table 2: Species list of Seed Mix B, which is rich in grasses; Seeds from annual Blanketflower (*Gaillardia *sp.) and Phacelia (*Phacelia tanacetifolia*) were added to this mix, approximately 1 lb each.*

Native Meadow Mix B				
Common Name	**Scientific Name**	**Percent of mix by volume (seed/ft2)**	**Final Mix Total pounds (lb) for 1.5 acres**	Supplier
Autumn Bentgrass	*Agrostis perennans*	15.0%	0.09	Ernst Seeds
Big Bluestem	*Andropogon geradii*	6.4%	2.12	Ernst Seeds
Blackeyed Susan	*Rudbeckia hirta*	6.3%	0.19	Ernst Seeds
Canada Wildrye	*Elymus canadensis*	10.7%	4.47	Ernst Seeds
Indiangrass	*Sorghastrum nutans*	6.7%	1.82	Ernst Seeds
Lance Leaved Coreopsis	*Coreopsis lanceolata*	3.2%	0.69	Ernst Seeds
Little Bluestem	*Schizachyrium scoparium*	16.0%	3.82	Ernst Seeds
Partridge Pea	*Chamaecrista fasciculata*	1.1%	0.78	Ernst Seeds
Purple Coneflower	*Echinacea purpurea*	5.3%	2.20	Ernst Seeds
Purple Lovegrass	*Eragrostis spectablis*	1.3%	0.06	Prairie Moon
Purple Prairie Clover	*Dalea purpurea*	2.1%	1.27	Ernst Seeds
Purpletop	*Tridens flavus*	16.4%	1.69	Ernst Seeds
Slender Lespedeza	*Lespedeza virginiana*	1.1%	0.65	Ernst Seeds
Switchgrass	*Panicum virgatum*	8.5%	1.57	Ernst Seeds
	TOTALS:	**100.00%**	**21.42 lbs**	

Figure 2: Images of plants included in Seed Mix A (first row: Lavender Hyssop, Dense Blazingstar, Black-eyed Susan, Smooth Blue Aster, Purple Prairie Clover, New England Aster; second row: Little Bluestem, Early Goldenrod, Brown-eyed Susan, Tall White Beardtongue, Roundheaded Lespedeza, Ohio Spiderwort; third row: Mistflower, Joe-Pye-Weed, Butterfly Milkweed, Showy Goldenrod, Partridge Pea, Purple Coneflower; fourth row: Narrowleaf Mountain-mint, Lance-leaved Coreopsis, Common Milkweed, Wild Bergamot, Slender Lespedeza); Pictures were copied from on-line seed catalogues, mostly by Prairie Moon

Figure 3: Images of plants included in Seed Mix B (first row: Autumn Bentgrass, Big Bluestem, Black-eyed Susan, Canada Wildrye, Indiangrass; second row: Lance-leaf Coreopsis, Little Bluestem, Partridge Pea, Purple Coneflower, Purple Lovegrass; third row: Purple Prairie Clover, Purpletop, Slender Lespedeza, Switchgrass)

Management:

First Season (2017): All experimental plots (those seeded with seed mixes A & B, as well as the control plots) were mowed to approximately 6-7 inches height three times during the first season. This was necessary to reduce shading of the slow-growing seedlings of the perennial native plants by the fast-growing annual weeds that had germinated from the seed bank and to limit the production of new weed seeds. The mowing was done on:

- 6-10 July 2017: with flail mower (6 hours total for 4.5 acres)
- 26/28 July 2017: with flail mower (6 hours total for 4.5 acres)
- 15/16 Aug 2017: with rotary mower (3 hours total for 4.5 acres)

No management occurred during the rest of the season and the vegetation was left standing into the winter.

Second Season (2018): By Spring of the second year, the native perennials had established dense stands and were not threatened by competition for light by early-season annual weeds any more. However, the perennial and non-native Red Clover, Hairy Vetch, Mugwort, Curly and Broad-leaved Dock, and Wild Carrot were growing vigorously in the experimental plots, and were reduced by selective weeding/string trimming in all nine experimental plots, including the control plots (50 hours total for 4.5 acres between 25 May and 15 June 2018). Other than that, no mowing was necessary in the experimental plots during the second season, and the vegetation was again left standing into the winter.

Monitoring Methods:

Vegetation Development:

Photographic Documentation: We documented the development of the vegetation in all nine experimental plots with a series of images taken from standard locations at monthly intervals.

Quantitative Vegetation Inventories: Twice a year (July & September), we documented the vegetation in ten evenly-spaced samples along two transects in each of the nine experimental plots. In ten square-shaped samples of one square foot, we recorded the % cover and maximum height of each plant species present. In ten larger circular samples of 3 feet radius (which included the square samples), we recorded the presence of all additional plant species.

Flower Abundance: We documented quantitatively the seasonal flower abundance by species. In each experimental plot, we counted or estimated the number of open flowers of each species in ten circular, three-foot radius samples spaced evenly along two transects. Species-specific flower abundance in each sample was calculated by multiplying the number of flowers by their average size (=flower or inflorescence area in mm^2). We then extrapolated this value to average % cover by each flower species within each experimental plot. Flower abundance was monitored twice in 2017 (Aug 10 and Sept 8; the newly seeded plants were slow to produce flowers in the first year, therefore, we only began documenting flower abundance later in the summer) and four times in 2018 (June 12, July 10, Aug. 9, Sept. 21; to represent the duration of the flowering period).

General Insect Monitoring: We documented the presence and abundance of insects in the experimental plots three times in 2017 (May, Aug., Oct.) and four times in 2018 (in June, July, Aug., and Sept.). In each of the nine plots, insects were sampled over a 24-hour period with a variety of traps. For a detailed description of the insect monitoring methods, please see the separate report, entitled "*Native Meadow Test Plots: 2018 Entomology Report*" by Conrad Vispo (14 Feb. 2019).

Monitoring of Flower-Visiting Insects: Flower-visiting insects were documented in the nine experimental plots every two weeks from June through September with standardized visual surveys conducted by Erin Allen as part of her graduate work at SUNY Albany. Again, a more detailed description of the specific methods is provided in a separate report, entitled "*Native Meadow Test Plots: 2018 Entomology Report*" by Conrad Vispo (14 Feb. 2019).

Soil Conditions: Three composite soil samples (composed of 10 samples each) were taken from each of the nine experimental plots annually in the spring (May 2, 2017 and May 7, 2018) and analyzed at the Cornell Soil Health Lab for their chemical, physical, and biological characteristics.

Labor and Equipment: We keep records of all management actions to document the labor and equipment used to establish and maintain these wildflower meadows.

Monitoring Results and Discussion:

Vegetation Development:

Appendices 1.1 through 1.9 are the photographic documentation of each of the nine experimental plots during the first two years. Appendices 2.1 through 2.3 show side-by-side photographic comparisons during the first two years for all plots organized by treatment, while. Appendices 3.1 through 3.3 show the same organized by trial area.

Figures 4 & 5 illustrate the results from the quantitative vegetation inventories in experimental plots seeded with Seed Mix A during the first two years. Figure 4 shows percent cover of seeded species and Figure 5 that of wild-growing species. Figures 6 & 7 show the same for experimental plots seeded with Seed Mix B. Figure 8 illustrates percent cover by wild-growing plants in the control plots.

There was a marked difference in vegetation development during the first season between the trial areas. In trial area NMT1 (Fig. 1), both seeded plots (A1 and B1) had better establishment of the seeded plants (reaching 40% and 25% cover respectively) by September 2017 than the same treatments in NMT2 and 3 (reaching at the most 15% and 10% cover, respectively; Fig. 4 & 6). This might have been in part due to the different crop history of NMT1, which had been in mixed vegetables in 2015 and consequently seemed to have a different weed seed bank. NMT2 has the sandiest soil and lowest water holding capacity of the trial areas, and there might have been less germination success and higher seedling mortality due to the relative dryness in this trial area. NMT3A has the highest heterogeneity of soil conditions within any of the experimental plots, including a large area (approximately 20% of the plot) that often has standing water after rains, but also dries to a hard pan during dry periods. Germination of seeded plants was low in this intermittently-waterlogged area of NMT3A during the first year.

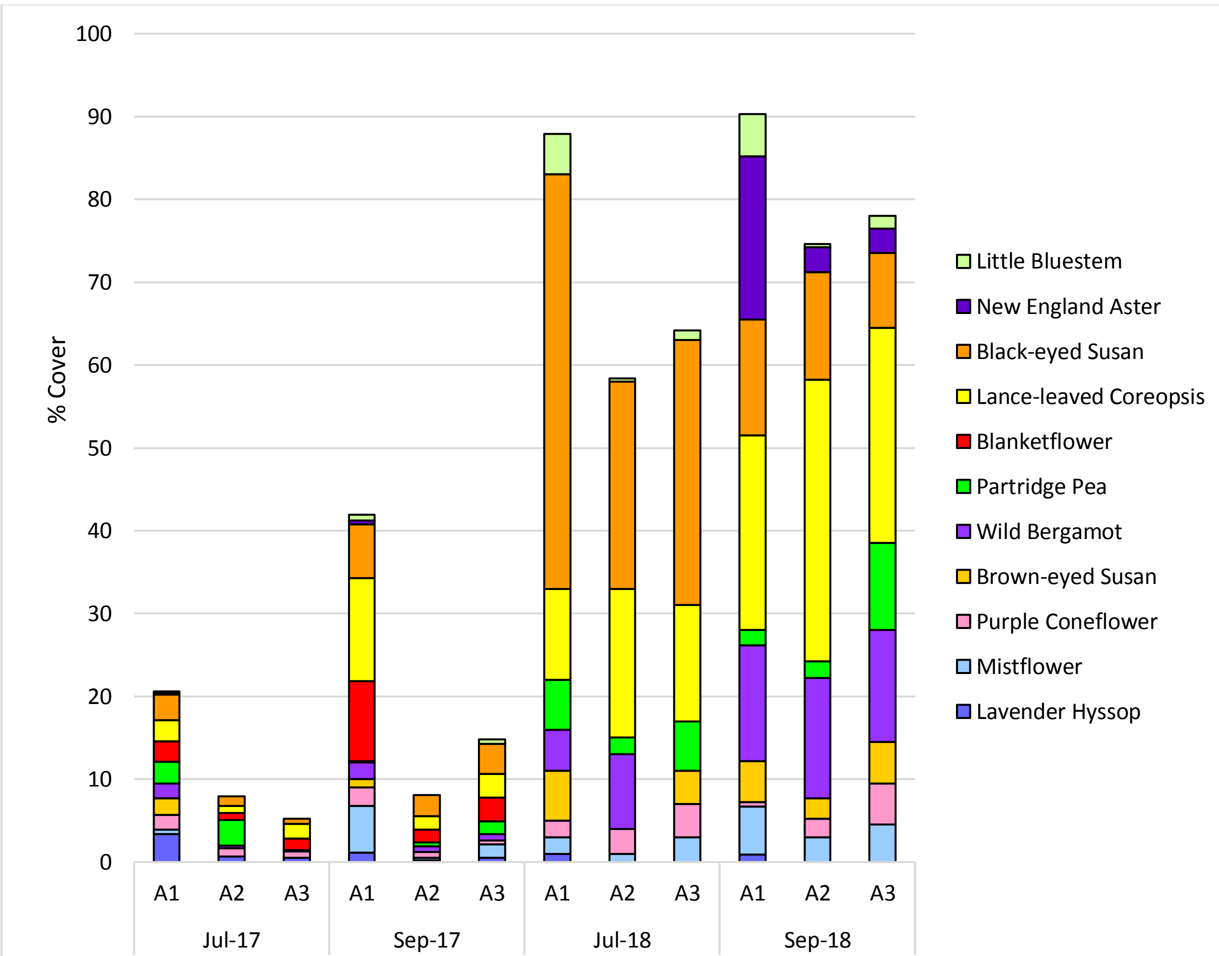


Figure 4: Development of Vegetation Composition (% cover of seeded species only) in Experimental Plots seeded with Seed Mix A (please note that A1, A2, and A3 refer to experimental plots NMT1A, NMT2A, and NMT3A, respectively)

During the second season, the seeded plants "took off" in all experimental plots (including in the intermittently waterlogged area of NMT3A), reaching between 70% and 90% cover in those seeded with Mix A (Fig. 4), and between 60% and 80% cover in those seeded with Mix B (Fig. 5). The density of seeded plants in NMT1A compared to NMT2A and NMT3A remained somewhat higher, but the difference became much less striking (Fig. 4). Although at the end of the 2017 season and into early 2018, NMT2A was densely covered with a mulch of Crabgrass stalks (App.

2.1), the seeded wildflowers eventually pushed through and reached almost the same density as in NMT3A (Fig. 4). The initial difference in percent cover by seeded plants between the three experimental plots seeded with Mix B did not persist into the second season (Fig. 6).

The wild-growing plants were clearly more abundant in NMT2A and 3A than in NMT1A at the end of the first season (Fig. 5), with Crabgrass covering 90% and 70% of NMT2A and NMT3A, respectively (App. 2.1). Crabgrass was also the dominant wild-growing plant in all other experimental plots at the end of 2017. During the second season, wild-growing plants were markedly less common in all experimental plots that had been seeded with Seed Mix A or B, and Horseweed replaced Crabgrass as the dominant wild-growing plant. By midsummer 2018, wild-growing plants were still somewhat more abundant in NMT2A and NMT3A compared to NMT1A, but that difference became much less prominent by September 2018 (Fig. 5). The most common wild-growing plants in NMT1A by that time were Cottonwood seedlings. Wild-growing plants were also more abundant in NMT2B and 3 B, compared to NMT1B and this difference persisted through both seasons, although the abundance of wild-growing plants in all three experimental plots seeded with Mix B decreased in 2018 (Fig. 7). While Crabgrass and Galinsoga were the dominant wild-growing plants in these three plots during the first season, Horseweed became more abundant in 2018 (Fig. 7).

The species in Seed Mix A did not all establish evenly. Although, during 2017, we found young plants of 19 of the 22 seeded wildflowers and of Little Bluestem in at least one of the experimental plots, we did not discover any young plants of Narrowleaf Mountainmint, Ohio Spiderwort, and probably also Joe-Pye-Weed (early records of this species from our plots were in retrospect most likely all misidentified young Mistflower plants). The seeded species that established themselves most abundantly and evenly during the first season were Black-eyed Susan, Lanceleaf Coreopsis, Partridge Pea, Purple Coneflower, and Blanketflower (an annual, which had been added to the seed mixes as an afterthought) and, to a lesser degree, Mistflower, Wild Bergamot, Lavender Hyssop, and Phacelia (another annual, which also had been added to the seed mixes) (Fig. 4).

In 2018, Lanceleaf Coreopsis and Black-eyed Susan became very common in the experimental plots that had been seeded with Seed Mix A (Fig. 4), but many other seeded species, such as Partridge Pea, Purple Coneflower, Brown-eyed Susan, Wild Bergamot, Lavender Hyssop, Mistflower, and—to a lesser degree--Dense Blazingstar, New England and Smooth Aster, Showy and Early Goldenrod, and Butterfly Milkweed increased in abundance, and even a few individuals of Narrowleaf Mountainmint and Ohio Spiderwort, which had not been seen during the first season, began to appear. Roundhead and Slender Lespedeza, Purple Priarie Clover, as well as Common Milkweed persisted through both seasons in small numbers. The only species that has not been detected during the first two seasons is Joe-Pye-Weed. Blanketflower and Phacelia, the two annual species which had been added to the seed mixes, flowered in 2017 but were absent in 2018.

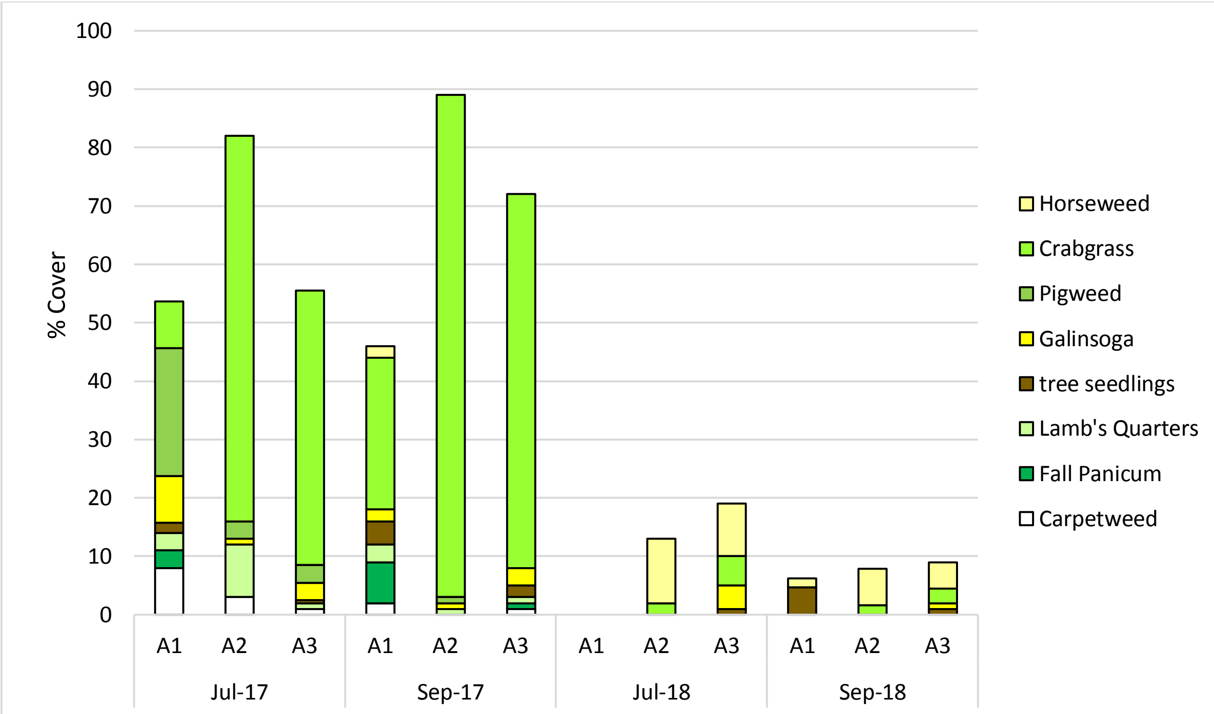


Figure 5: Development of Vegetation Composition (% cover of wild-growing species only) in Experimental Plots seeded with Seed Mix A (please note that A1, A2, and A3 refer to experimental plots NMT1A, NMT2A, and NMT3A, respectively; note also that we did not find any wild-growing species in our vegetation samples of NMT1A in July 2018!)

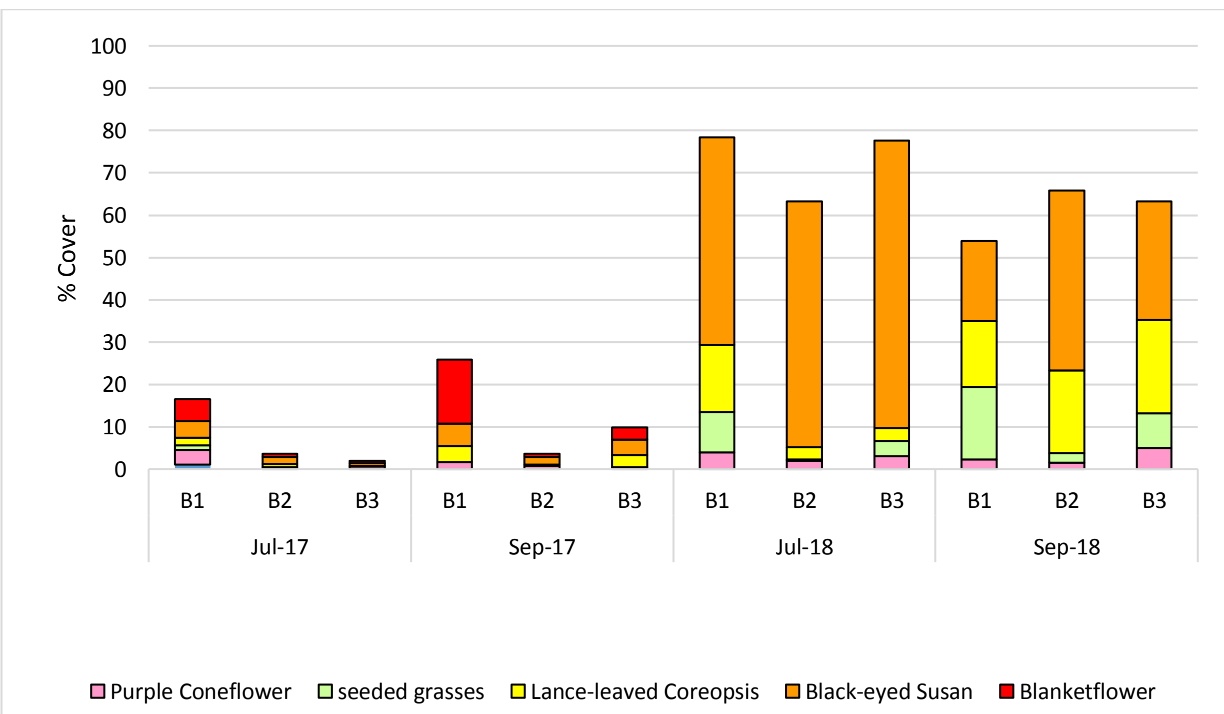


Figure 6: Development of Vegetation Composition (% cover of seeded species only) in Experimental Plots seeded with Seed Mix B (please note that B1, B2, and B3 refer to experimental plots NMT1B, NMT2B, and NMT3B, respectively)

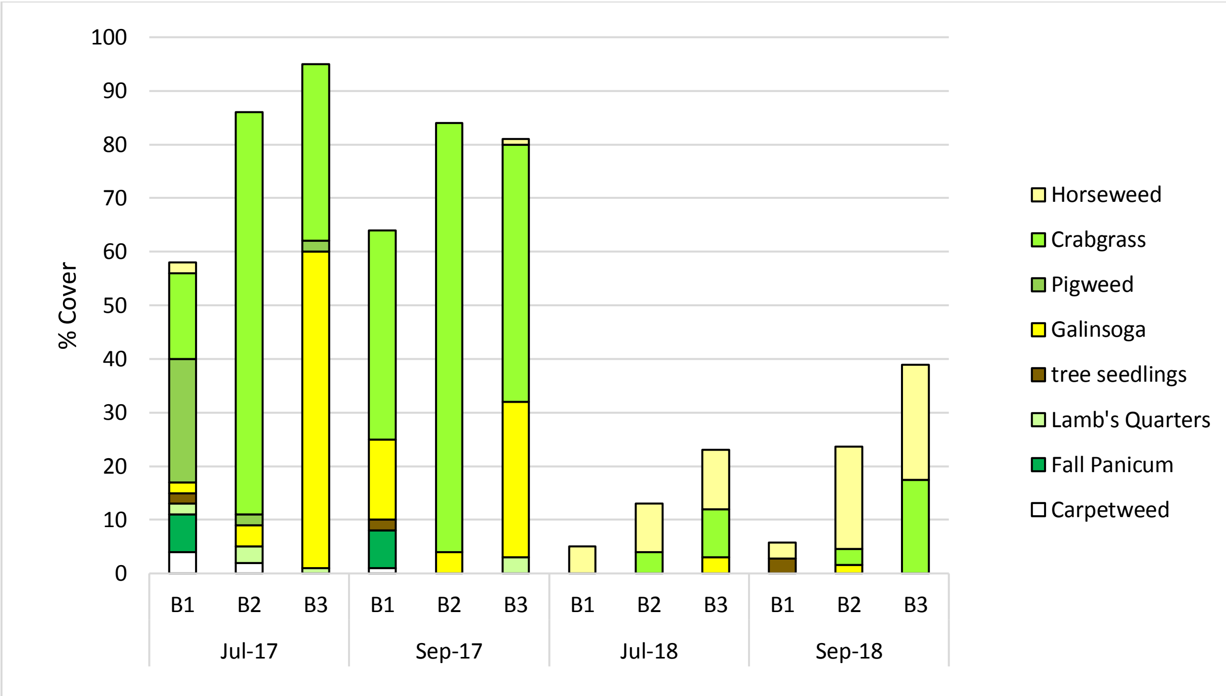


Figure 7: Development of Vegetation Composition (% cover of wild-growing species only) in Experimental Plots seeded with Seed Mix B (please note that B1, B2, and B3 refer to experimental plots NMT1B, NMT2B, and NMT3B, respectively)

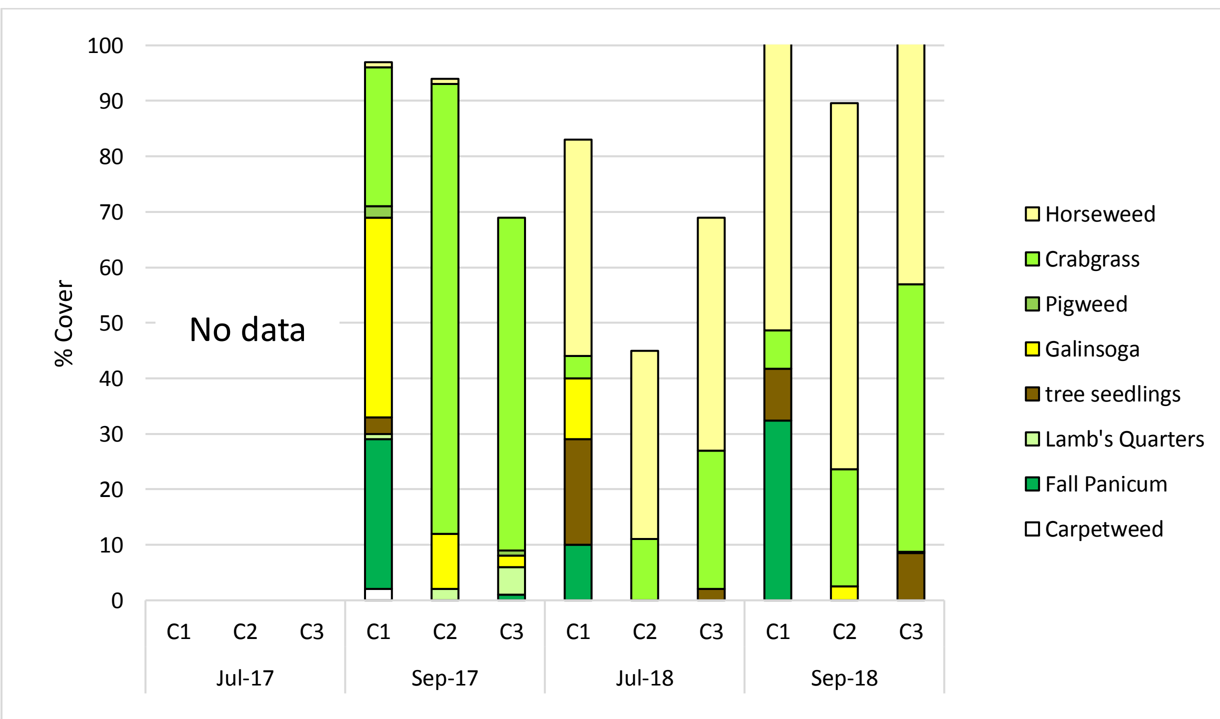


Figure 8: Development of Vegetation Composition in Control Plots; Horseweed reached approximately 80% cover, creating a canopy above a layer of shorter plants in Experimental Plots C1 and C3 in September 2018; consequently, the total % cover added to more than 100% in these plots (please note that C1, C2, and C3 refer to experimental plots NMT1C, NMT2C, and NMT3C, respectively)

In the experimental plots seeded with Seed Mix B, the dominant species during the first season were Black-eyed Susan, Lanceleaf Coreopsis, and Blanketflower (Fig. 6). The last did not persist into the second season. Of the native grasses, Little Bluestem and Canada Wildrye were most noticable in 2017. In 2018, we documented all seeded native grasses except Purple Lovegrass. Black-eyed Susan and Lanceleaf Coreopsis continued to be abundant, but Purple Coneflower was also quite common (Fig. 6). Partridge Pea persisted in low density through both years, while Slender Lespedeza and Purple Prairie Clover were not observed during the first two seasons in any of the experimental plots seeded with Seed Mix B.

The control plots were dominated by Crabgrass and Galinsoga during the first season, and by Horseweed in 2018. Tree seedlings (mostly Cottonwood) also became quite abundant in 2018 (Fig. 8).

Flower Abundance:

Figure 9 shows the average flower abundance (quantified as percent of the experimental plot covered by flowers) of the most common flowers in the three plots seeded with Seed Mix A.

Figure 10 compares the average flower abundances in the three experimental plots seeded with Seed Mix A, Seed Mix B, and the control plots, scaling the vertical axes even more to amplify the differences in flower abundance between 0 and 5% cover of the experimental plot.

Figure 11 compares the average diversity (quantified as species richness) of seeded and wild-growing plant species in flower in the experimental plots throughout the first two seasons.

While Lance-leaved Coreopsis flower abundance peaked in June (Fig. 9) and suffused the experimental plots with some light yellow (see App. 1.1 for NMT1A, App. 1.4 for NMT2A, and App. 1.7 for NMT3A), Black-eyed Susan flowers became very abundant in July (Fig. 9) and created a stunning visual display of a warm yellow (see App. 1.1 for NMT1A, App. 1.4 for NMT2A, and App. 1.7 for NMT3A). By August, most of the Black-eyed Susan flowers had wilted, and Wild Bergamot (*Monarda fistulosa*) was the most abundant flower, covering more area than Lance-leaved Coreopsis in June, but only 1/10th of the area covered by Black-eyed Susan in July. Although total flower abundance was substantially less in August compared to July, flower diversity was highest in August (Fig. 11), with Wild Bergamot, Black-eyed Susan, Brown-eyed Susan, and Partridge Pea providing most flowers (Fig. 9). By mid-September, total flower abundance increased again (Fig. 9) and flower diversity stayed high (Fig. 11), as the remaining Black-eyed Susan flowers and the increasing Brown-eyed Susan flowers were joined by those of New England Aster and a number of less abundant flowers from seeded plants.

Seed Mix B resulted in a much lower peak of Lance-leaved Coreopsis in June, with only approximately 25% of the flower abundance observed in Seed Mix A at the same time (Fig. 10 and see App. 3.1, 3.2, and 3.3 for side-by-side comparisons of Mix A and B in NMT1,2, and 3, respectively). This was to be expected, because the seeding rate for Lance-leaved Coreopsis in

Mix B was less than half that in Mix A. White Clover (not seeded!) also contributed an appreciable amount of flowers in June in the experimental plots seeded with Seed Mix B. In July, Seed Mix B was even more dominated than Seed Mix A by the flowers of Black-eyed Susan (App. 3.1 – 3.3). Also present were small amounts of flowers of Lance-leaved Coreopsis, as well as White Clover, Wild Carrot, and Annual Fleabane (the last three not seeded). In August, there was still a considerable amount of Black-eyed Susan flowers, accompanied by Wild Carrot and Horseweed. By September, there were very few flowers left in Seed Mix B, and they were mostly of Black-eyed Susan. Throughout the 2018 season, Mix B had—as expected-- a lower diversity of flowers than Seed Mix A. However, the lack of diversity in the seed mix was compensated for by a higher diversity of wild-growing flowers (Fig. 11).

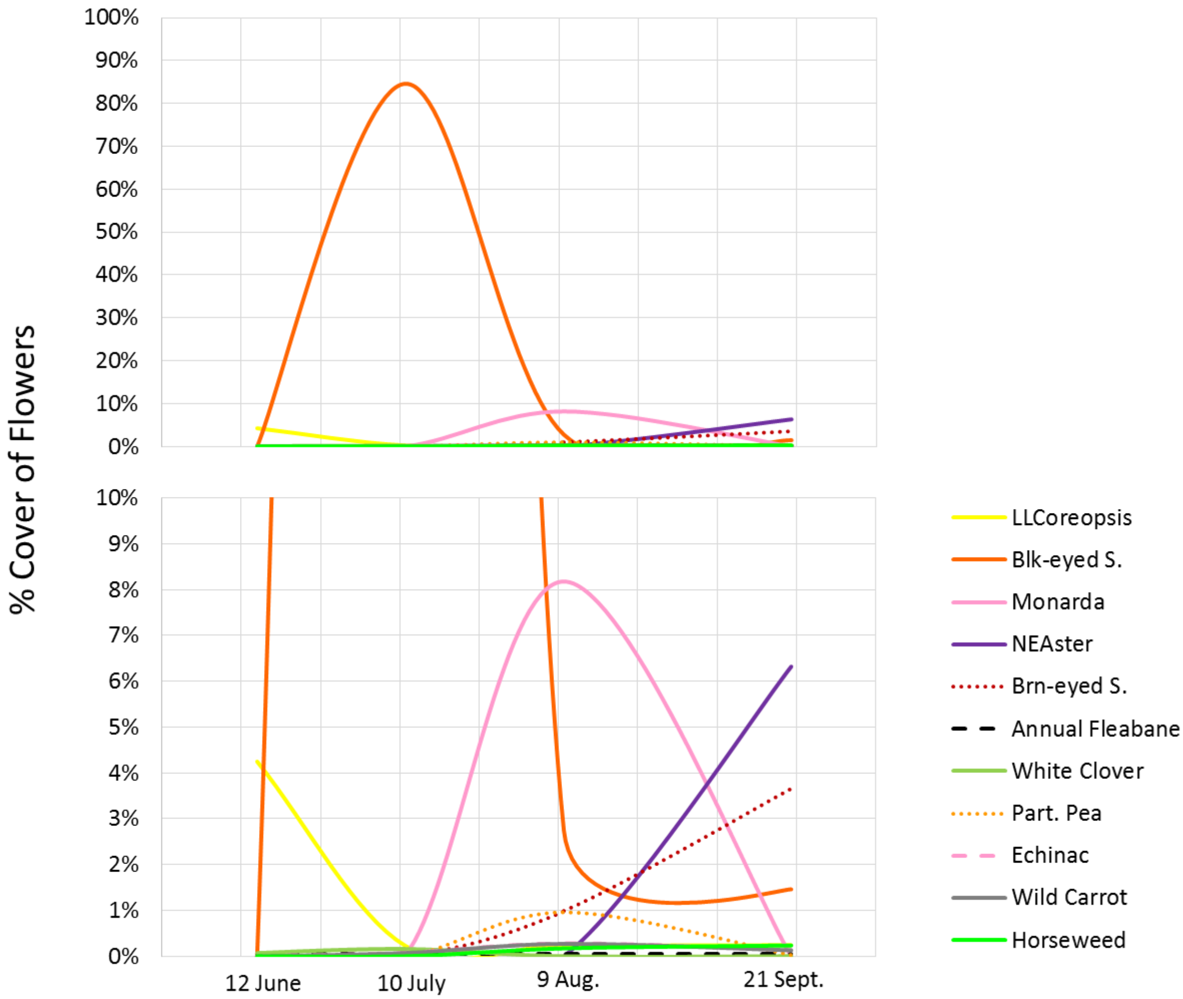


Figure 9: Average flower abundance of the most common flowers throughout 2018 in the three plots seeded with Seed Mix A. Both charts show the same data, but the vertical axis ranges from 0 to 100% (of the plot's area covered by flowers) in the upper chart and from 0 to 10% in the lower chart in order to magnify the pattern in this lower range.

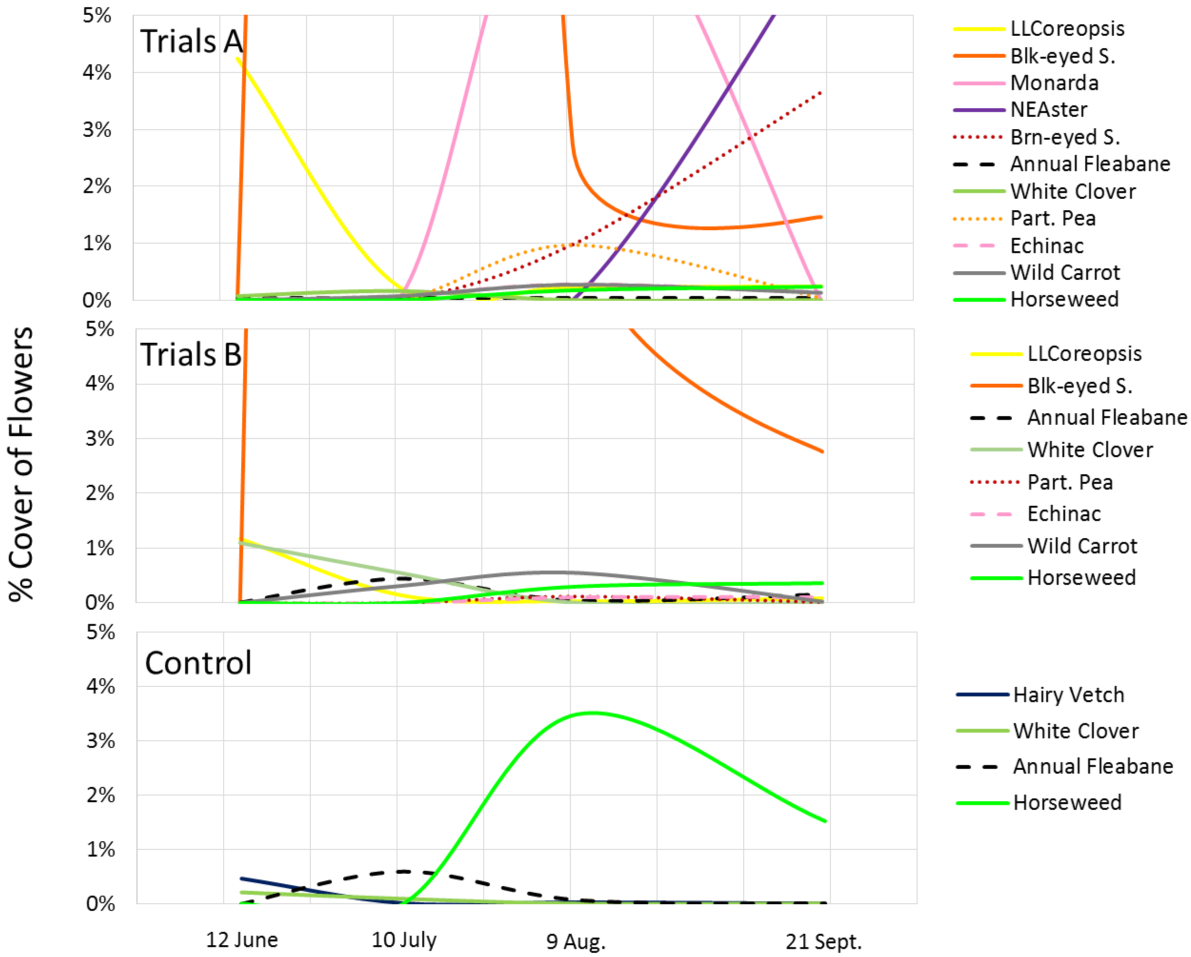


Figure 10: Comparison of Average Flower Abundance in the three plots seeded with Seed Mix A (top), Seed Mix B (middle), and the three control plots (bottom). Note that all three vertical axes are scaled to represent a range from 0 to 5% flower cover. Consequently, the Black-eyed Susan flower peaks in July in Trials A and B, as well as the Monarda *peak in August and the New England Aster peak in September in Trials A, are off the charts.*

The control plots had very little Hairy Vetch and White Clover flowers in June, a small peak of Annual Fleabane Flowers in July, and an abundance of Horseweed flowers in August. By September, there were also very few flowers left in the control plots, and these were mostly of Horseweed (Fig. 10). Figure 11 illustrates a steady decline of flower diversity in the control plots throughout the 2018 season. Early successional weeds of tilled ground provided a variety of flowers--although not in large abundance—early in the season, but seemed to have gotten largely crowded out by the dense growth of Horseweed that developed in the control plots throughout the summer.

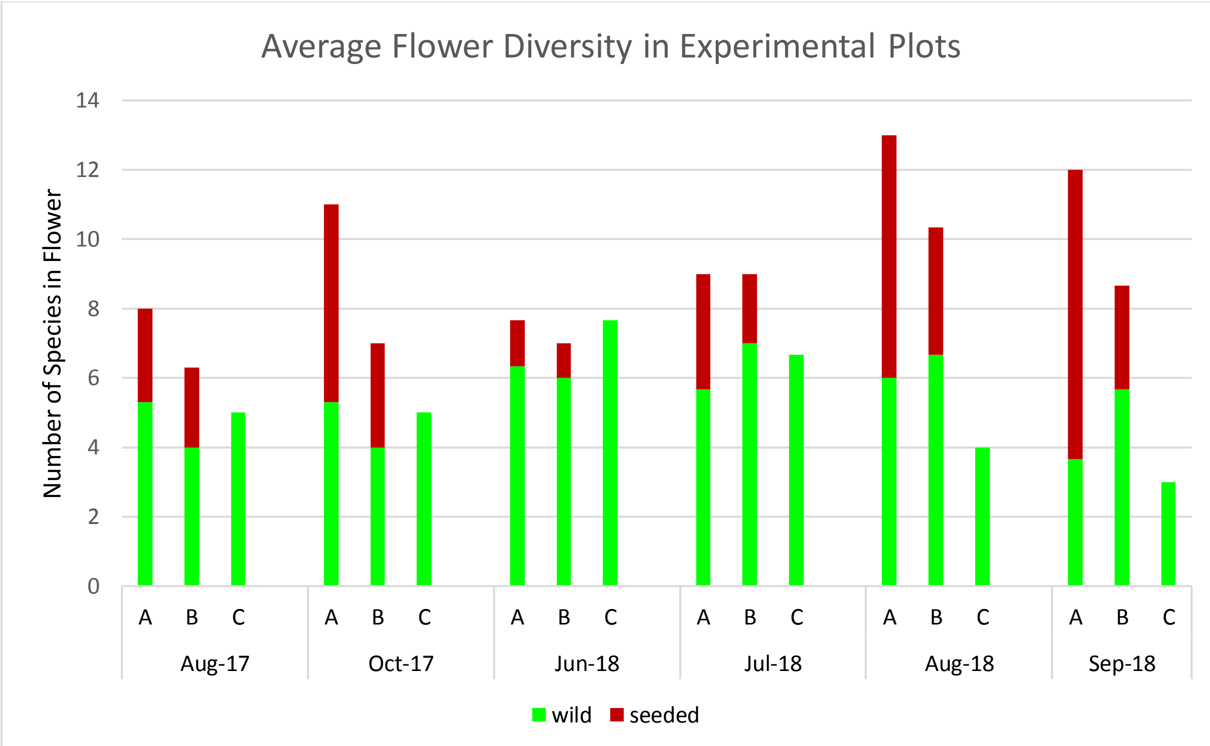


Figure 11: Average number of flowering species present in the experimental plots during the first two seasons. The green bars represent wild-growing species in flower, the red bars represent species in flower that had been seeded.

General Insect Monitoring: The results from the general insect monitoring are summarized in a separate report, entitled "*Native Meadow Test Plots: 2018 Entomology Report*" by Conrad Vispo (14 Feb. 2019).

Monitoring of Flower Visiting Insects: The results from the monitoring of flower visiting insects are currently being analyzed by Erin Allen as part of her graduate work at SUNY Albany and will be presented fully in her thesis in May 2019. Some of these data are included in "*Native Meadow Test Plots: 2018 Entomology Report*".

Soil Conditions: The soil samples taken in spring of 2017 (before the plots were seeded) and in spring of 2018 were analyzed by the Cornell Soil Health Lab. As part of the Soil Health Lab report, the values for the different soil variables were ranked by comparing them to a comprehensive database of agricultural soils throughout the US and beyond. This ranking indicated a good pH range and high-to-excessive phosphorous values in all experimental plots. Potassium was ranked perfect for trial areas NMT1 and NMT3, but low for NMT2. Organic matter, active soil carbon, soil protein, subsurface hardness and even surface hardness were ranked low in all trial areas. Aggregate stability also ranked very low overall, only experimental plot NMT2A ranked slightly better. Soil respiration ranked overall low, but worst in experimental plot NMT2A. Root pathology was very variable across the experimental plots, with NMT2A ranking worst and NMT1A pretty good. Water holding capacity was ranked high in trial areas NMT1 and 3, but only intermediate in NMT2 (worst in NMT2A and B).

Figure 12 illustrates the differences in soil texture between the experimental plots. Trial area NMT2 has the sandiest soils (classified as sandy loam to loamy sand), while NMT3 has the siltiest (classified as sandy loam, loam, and silt loam). The soils of trial area NMT1 are intermediate in their soil texture (classified as sandy loam and loam).

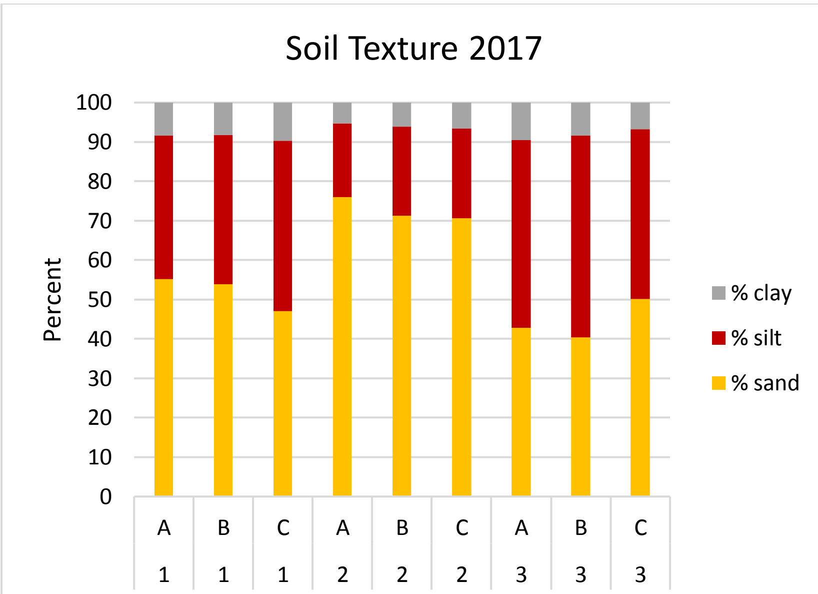


Figure 12: Soil texture of the experimental plots according to the 2017 soil samples (please note that 1A, 1B, 1C, etc. refers to experimental plots NMT1A, NMT1B, NMT1C, etc., respectively).

The 2018 test results indicated that across all experimental plots, the soils seem to have changed somewhat since 2017. This is not surprising, because—after years of frequent tillage—the soils in all experimental plots had been left untilled for an entire year between the testing dates. However, there was no indication of any consistent differences in the soils due to experimental treatments (Mix A, Mix B, or control).

Across all experimental plots, there was a 40% increase in organic matter (from an average of 1.1% in 2017 to 1.5% in 2018), a 50% increase in active carbon (from an average of 184ppm in 2017 to 278ppm in 2018), and a 30% increase in soil respiration (from an average of 0.35 mg CO_2/g dry matter in 2017 to 0.45 mg CO_2/g dry matter in 2018). While this seems to be a considerable improvement, due most likely to the fact that between the two testing dates permanent vegetation got established on all experimental plots (there was no tilling and no plant material was removed), it is important to note that the 2018 samples were still rated quite low by the Cornell Soil Health Lab in respect to their organic matter and active carbon (average scores 20 of 100), as well as soil respiration (average score 30 of 100).

Water holding capacity showed a very slight increase in most experimental plots and an appreciable increase in NMT2A & B. Root pathology also might have improved slightly across all experimental plots.

Aggregate stability, soil protein and pH showed no appreciable change during the first year of the trial across the experimental plots.

The somewhat excessive phosphorus levels from 2017 came down to what the Cornell Soil Health Lab considers close to ideal levels in 2018 in all experimental plots.

The potassium levels, which were rated as quite good by the Cornell Soil Health Lab in 2017 improved even further and were ideal across all experimental plots in 2018.

Potentially mineralizable nitrogen decreased by approximately 20% across all experimental plots (from an average of 7.0 µgN/g dry matter/week in 2017 to 5.6 µgN/g dry matter/week in 2018).

Labor and Equipment: Starting with the site preparation in early Spring 2017, Table 4 lists the management actions taken to date in the Native Meadow Trials in chronological order, specifies the equipment used and the time spent (in person hours per acre). Not counting the site preparation work (seeding to Rye and then to Oats) completed in 2016, the site preparation for the actual seeding (starting with a cover of winter-killed Oats and some volunteer Rye growing back in (see the images from April 12, 2017 in Appendices 1.1 through 1.9) took a total of 1.5 person-hours per acre. The seeding itself (including the mixing of the seeds and calibration of the seeder) took 6 person-hours per acre. Mowing during the first season required a total of 3.3 person-hours per acre. Selective weeding/mowing during the second season required a total of 11 person-hours per acre.

Table 3: List of Management Activities in the Native Meadow Trials

Date	Action	Labor (person hrs/acre)	Equipment
April to mid May 2017	1st Harrowing	0.5	Perfecta II Harrow with S-tines equipped
April to mid May 2017	2nd Harrowing	0.5	Perfecta II Harrow with S-tines equipped
April to mid May 2017	3rd Harrowing	0.5	Perfecta II Harrow with S-tines equipped
May 19, 2017	Seeding	5.0	Great Plains No Till Seeder
May 25, 2017	Seeding	1.0	by hand
July 6-10, 2017	Mowing	1.3	Flail Mower
July 26-28, 2017	Mowing	1.3	Flail Mower
Aug. 15/16, 2017	Mowing	0.7	Rotary Mower
late May to mid June 2018	Selective Weeding/ Mowing	11.0	String Trimmer; by hand

Conclusions:

We successfully established two types of native meadows (plus a control) in three 1.5-acre trial areas on former corn fields at the Hudson Valley Farm Hub. This was accomplished without the use of herbicides, but required repeated shallow harrowing to prepare a weed-free seed bed. After seeding, the maintenance effort during the first two seasons of the meadows was approximately 11 person-hours per acre per year. The more diverse seed mix resulted in more flowers and the presence of flowers throughout the second season (June through October) and, as detailed in the accompanying "*Entomology Report*", attracted more pollinators (butterflies, bumblebees, and possibly hover flies, Honey Bees, and other bees) than the less diverse seed mix or the unseeded control. We were encouraged by the fact that, at least in 2018, certain pest insects (Tarnished Plant Bugs, weevils, and flea beetles) appeared to be less common in the seeded meadows than in the weedy control plots. However, wasps as a group (most of which are considered beneficial), did not seem to be particularly attracted to the seeded meadows, and may even have favored the control. In addition, some pests (such as leafhoppers and aphids) were more widely distributed, occurring in high numbers in both native meadows and the control.

We are looking forward to another year of sampling to see if the patterns in insect distribution persist and if any of the seeded native plants might yet get established. We will also try to include more shallow-flowered plants into future native meadow/nectary seed mixes to try to attract more beneficial wasps, as well as the pollinators.

Acknowledgements:

I thank Kelly Gill of the Xerces Society for her advice and patience in answering all my questions; the farmers at the Farm Hub for all their help with the preparation, establishment, and management of the test plots; Erin Allen, Brenna Bushey, Dylan Cipkowski, Julia Meyer, Rosa Villegas, and Conrad Vispo for their assistance with the data collecting and analyzing; and Anne Bloomfield for helping coordinate it all.

Appendix 1.1 Photographic documentation of the experimental plots: Native Meadow Trial 1A

NMT 1A through its first year (2017)

NMT 1A through its second year (2018)

Appendix 1.2 Photographic documentation of the experimental plots: Native Meadow Trial 1B

NMT 1B through its first year (2017)


12-April-2017 (3 harrowings)


18-May-2017 (day before seeding)


8-June-2017


3-July-2017 (mowed 6 July)


11-July-2017 (mowed 28 July)


4-Aug-2017 (mowed 15 August)


8-Sep-2017 (after 3 cuts)


3-Nov-2017


14-Dec-2017

NMT 1B through its second year (2018)


27-April-2018


25-May-2018 (selectiveweeding)


19-June-2018


10-July-2018


9-Aug-2018


13-Sept-2018


24-Sept-2018


23-Oct-2018

Appendix 1.3 Photographic documentation of the experimental plots: Native Meadow Trial 1C

NMT 1C through its first year (2017)

12-April-2017 (3 harrowings)

18-May-2017 (day before seeding)

8-June-2017

3-July-2017 (mowed 6 July)

11-July-2017 (mowed 28 July)

4-Aug-2017 (mowed 15 August)

8-Sep-2017 (after 3 cuts)

3-Nov-2017

14-Dec-2017

NMT 1C through its second year (2018)

27-April-2018

25-May-2018 (selectiveweeding)

19-June-2018

10-July-2018

9-Aug-2018

13-Sept-2018

24-Sept-2018

23-Oct-2018

Appendix 1.4 Photographic documentation of the experimental plots: Native Meadow Trial 2A

NMT 2A through its first year (2017)


12-April-2017 (3 harrowings)


18-May-2017 (day before seeding)


8-June-2017


3-July-2017 (mowed 6 July)


11-July-2017 (mowed 28 July)


4-Aug-2017 (mowed 15 August)


8-Sep-2017 (after 3 cuts)


3-Nov-2017


14-Dec-2017

NMT 2A through its second year (2018)


27-April-2018


25-May-2018 (selectiveweeding)


19-June-2018


10-July-2018


9-Aug-2018


13-Sept-2018

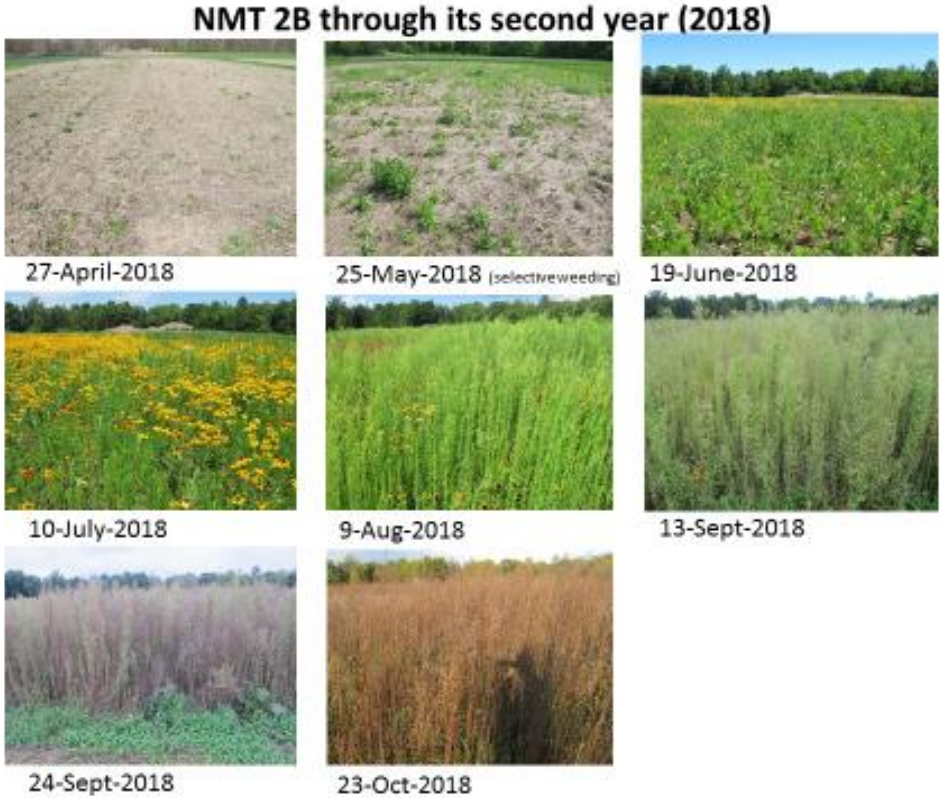

24-Sept-2018


23-Oct-2018

Appendix 1.5 Photographic documentation of the experimental plots: Native Meadow Trial 2B

NMT 2B through its first year (2017)

NMT 2B through its second year (2018)



Appendix 1.6 Photographic documentation of the experimental plots: Native Meadow Trial 2C

NMT 2C through its first year (2017)

NMT 2C through its second year (2018)

Appendix 1.7 Photographic documentation of the experimental plots: Native Meadow Trial 3A

NMT 3A through its first year (2017)


12-April-2017 (3 harrowings)


18-May-2017 (day before seeding)


8-June-2017


3-July-2017 (mowed 6 July)


11-July-2017 (mowed 28 July)


4-Aug-2017 (mowed 15 August)


12-Sep-2017 (after 3 cuts)


3-Nov-2017


14-Dec-2017

NMT 3A through its second year (2018)


27-April-2018


25-May-2018 (selectiveweeding)


19-June-2018


10-July-2018


9-Aug-2018


13-Sept-2018


24-Sept-2018


23-Oct-2018

Appendix 1.8 Photographic documentation of the experimental plots: Native Meadow Trial 3B

NMT 3B through its first year (2017)


12-April-2017 (3 harrowings)


18-May-2017 (day before seeding)


8-June-2017


3-July-2017 (mowed 6 July)


11-July-2017 (mowed 28 July)


4-Aug-2017 (mowed 15 August)


12-Sep-2017 (after 3 cuts)


3-Nov-2017


14-Dec-2017

NMT 3B through its second year (2018)


27-April-2018


25-May-2018 (selectiveweeding)


19-June-2018


10-July-2018


9-Aug-2018


13-Sept-2018


24-Sept-2018


23-Oct-2018

Appendix 1.9 Photographic documentation of the experimental plots: Native Meadow Trial 3C

NMT 3C through its first year (2017)

12-April-2017 (3 harrowings)

18-May-2017 (day before seeding)

8-June-2017

3-July-2017 (mowed 6 July)

11-July-2017 (mowed 28 July)

4-Aug-2017 (mowed 15 August)

12-Sep-2017 (after 3 cuts)

3-Nov-2017

14-Dec-2017

NMT 3C through its second year (2018)

27-April-2018

25-May-2018 (selectiveweeding)

19-June-2018

10-July-2018

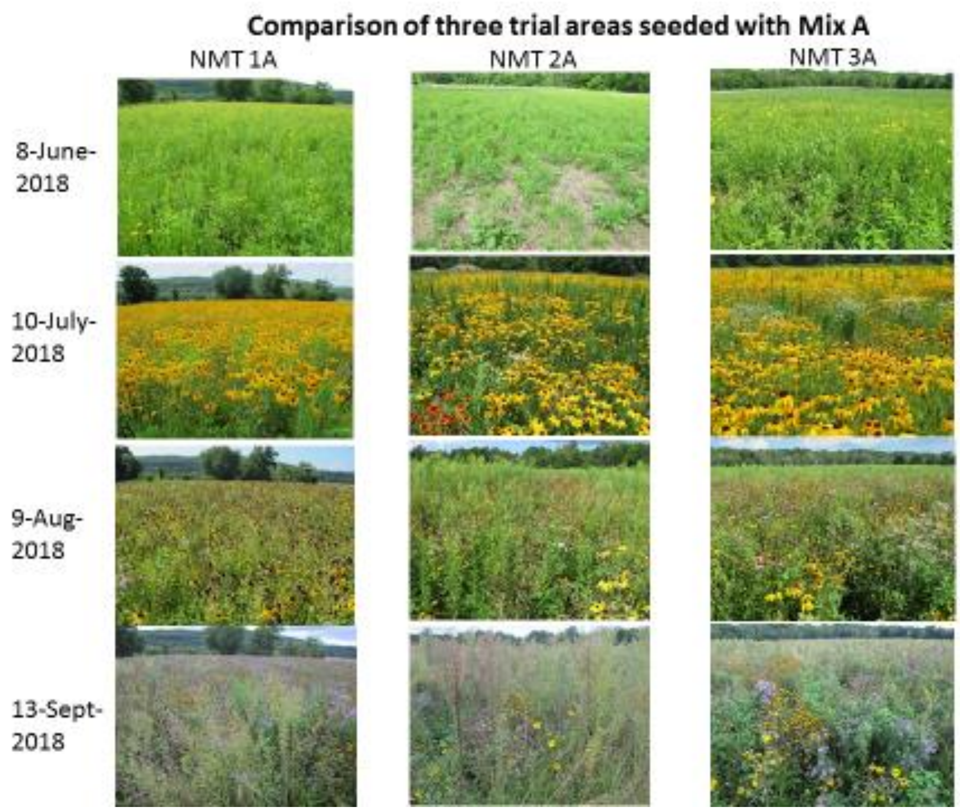
9-Aug-2018

13-Sept-2018

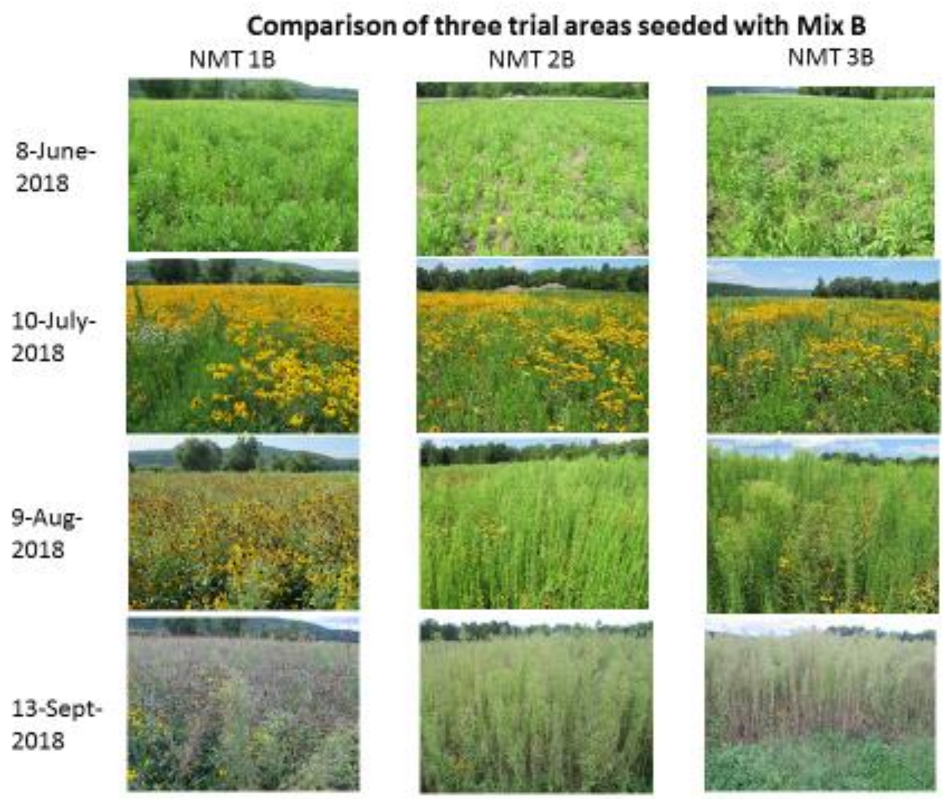
24-Sept-2018

23-Oct-2018

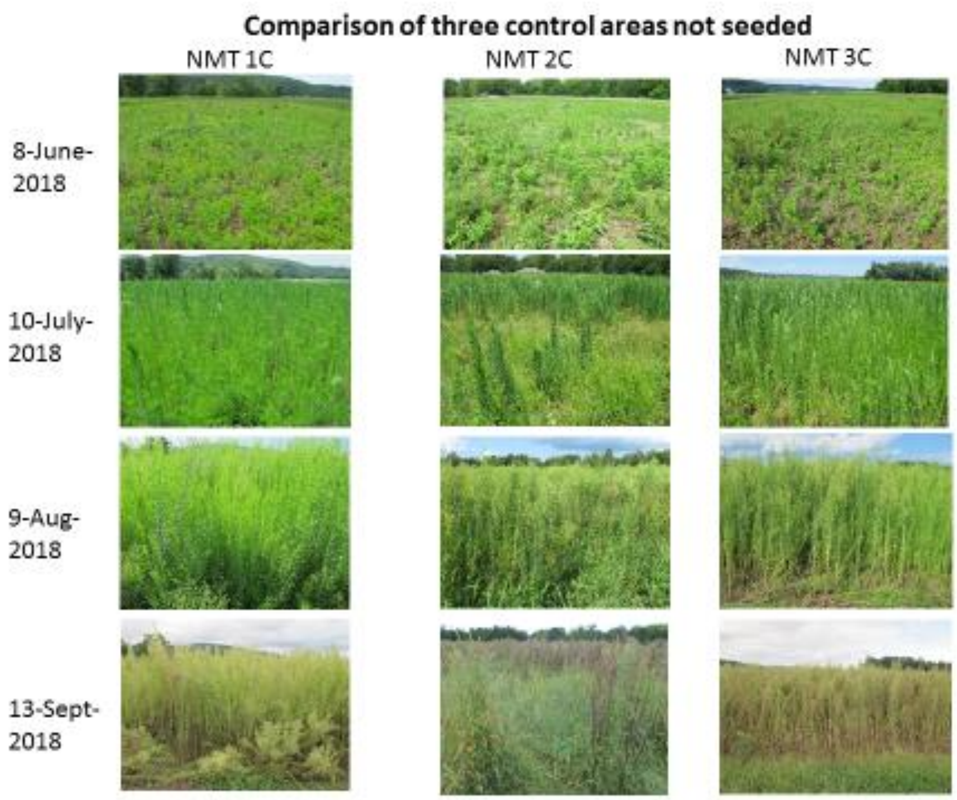
Appendix 2.1 Photographic comparison of the three experimental plots seeded with Seed Mix A



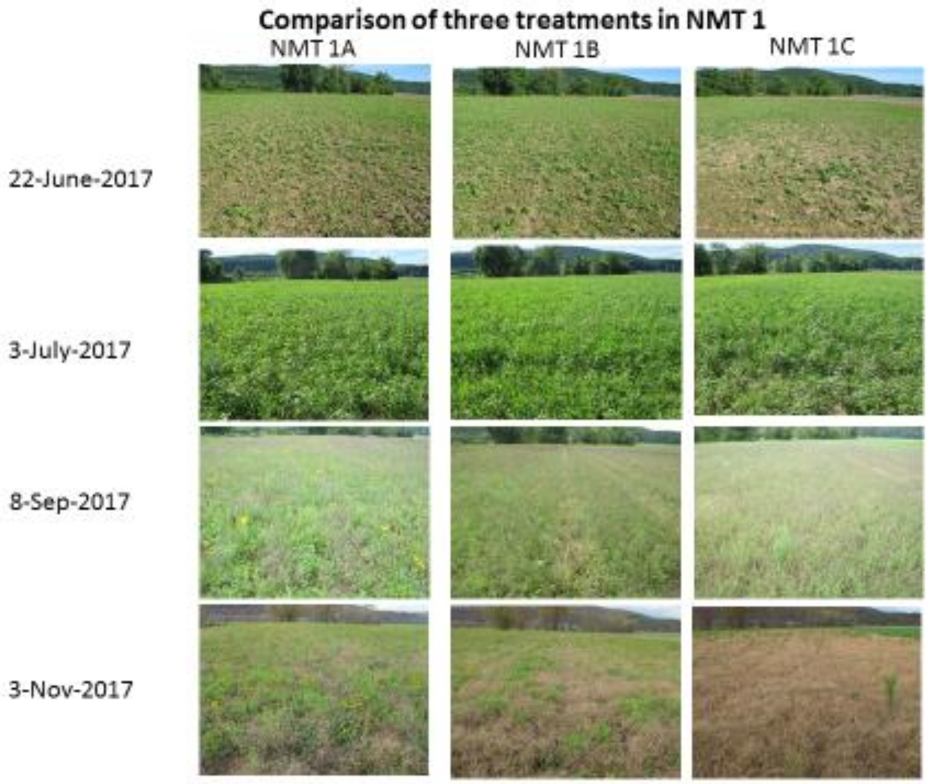
Appendix 2.2 Photographic comparison of the three experimental plots seeded with Seed Mix B

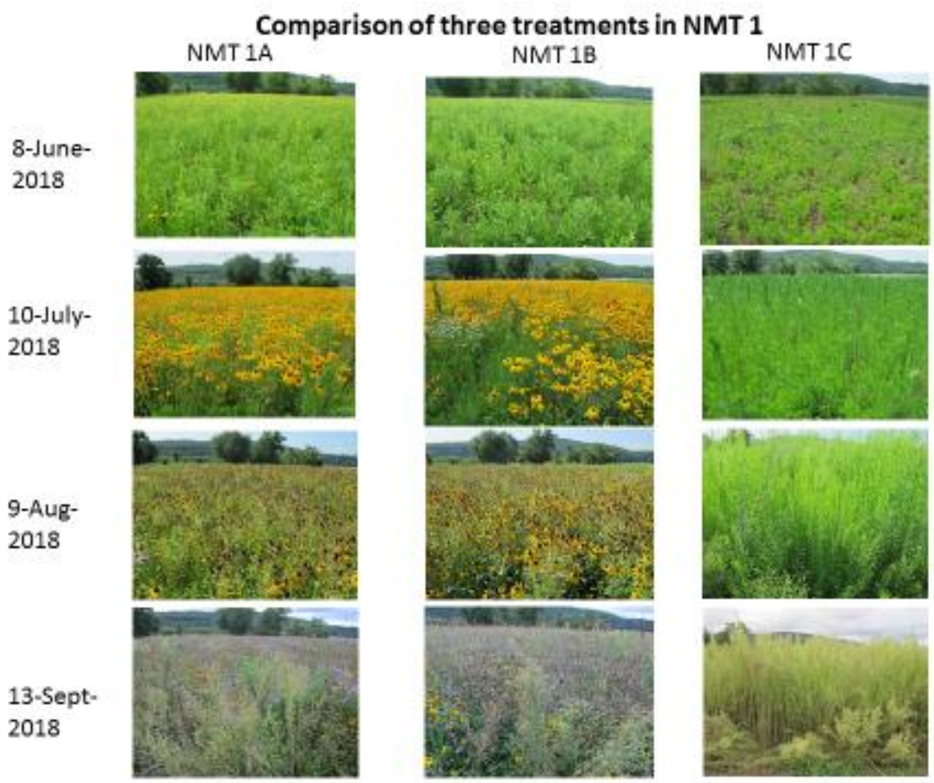


Appendix 2.3 Photographic comparison of the three control plots

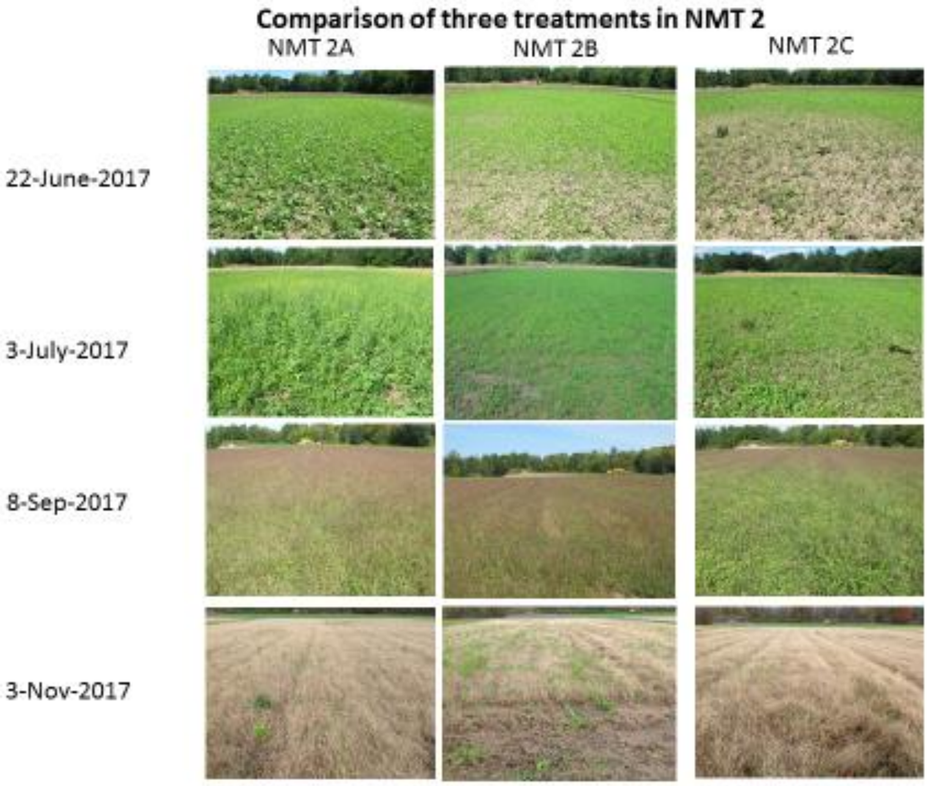


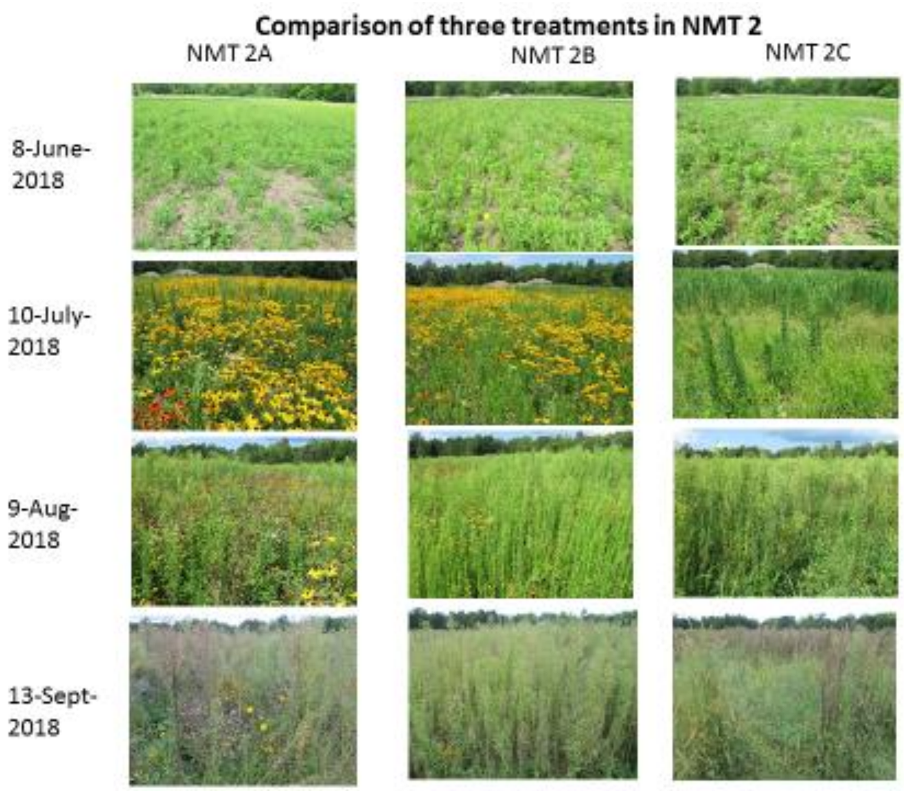
Appendix 3.1 Photographic comparison of the three treatments (seeded with Seed Mix A, seeded with Seed Mix B, and control) in trial area NMT1



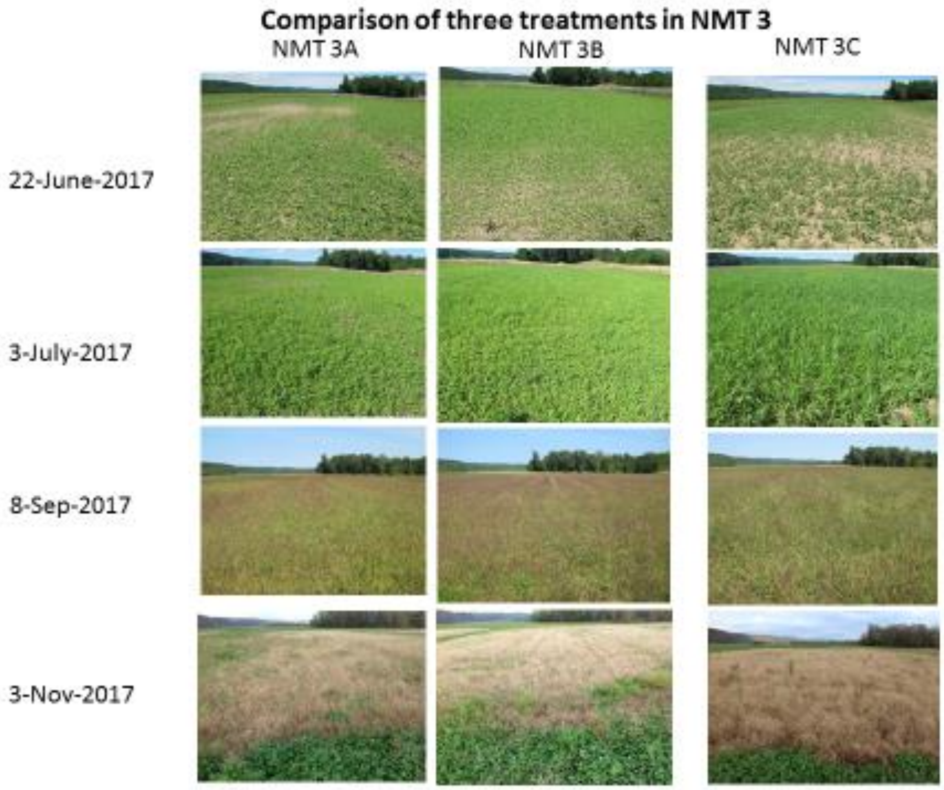


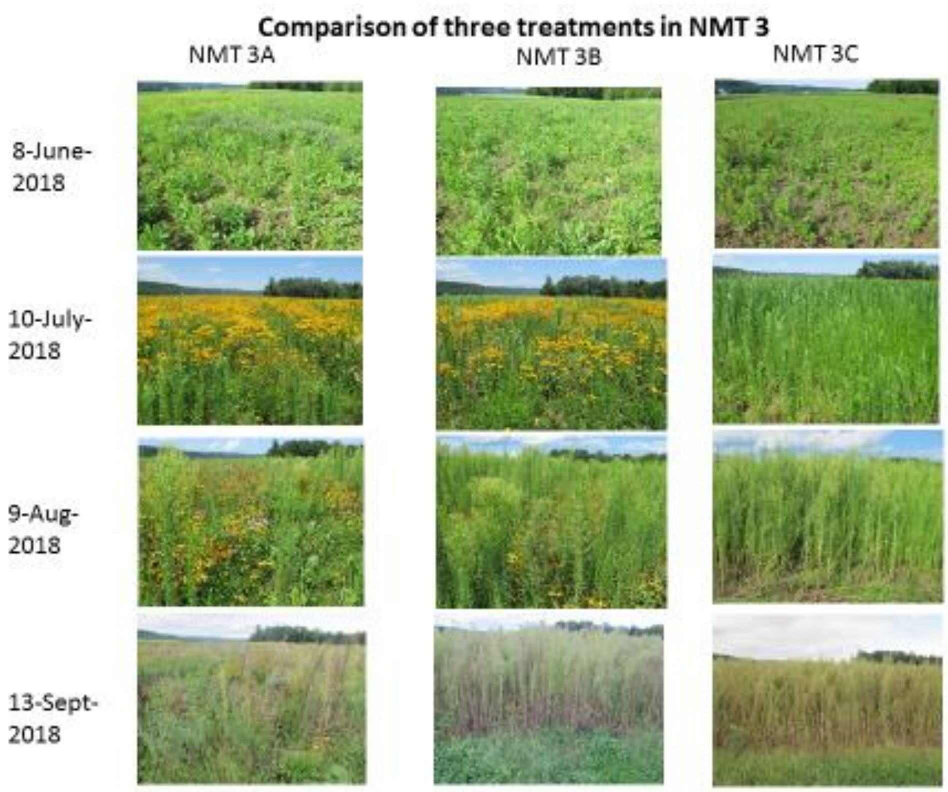
Appendix 3.2 Photographic comparison of the three treatments (seeded with Seed Mix A, seeded with Seed Mix B, and control) in trial area NMT2





Appendix 3.3 Photographic comparison of the three treatments (seeded with Seed Mix A, seeded with Seed Mix B, and control) in trial area NMT3





15 February 2019

Native Meadow Trial: 2018 Entomology Report

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(with extensive field and laboratory help from Dylan Cipkowski, Kenny Fowler, Erin Allen, Brenna Bushey and Julia Meyer)

Introduction

One of the central goals of the native meadow trial (NMTs for short) is to experiment with seed mixes which might attract and/or support some of the beneficials in the farm landscape, without providing undue support to pests. We can test our success in achieving that goal by comparing the insect (herein used as a shorthand for 'insects and spiders') abundances between different seed mixes and the unseeded control plots. The assumption, largely untested at least in our case, is that were we to find a seed mix that accomplished the above goal then planting it in proximity to crops would increase the net agroecological benefits experienced by those crops.

Although many beneficials clearly require pollen and/or nectar during their life cycles, regional data like ours has value for several reasons. First, not all flowers are equally valuable to all insects and so finding a seed mix that grows well in a given area and attracts a wide range of the regional beneficials is not a simple task; reports from work done elsewhere can be helpful, but there is also a large place-specific component. Furthermore, plantings can attract not only beneficials, but also pests; this again is a place-specific question depending in part upon the characteristics of the successful floral community and the regional pest fauna. Finally, context matters. There is evidence in the literature that the importance of on-farm habitat for supporting at least certain beneficials depends in part on the relative rarity of those resources elsewhere in the landscape. For NRCS, Xerces and others interested in promoting planted wild flower meadows in the mid-Hudson Valley so as to enhance beneficials, it is thus useful to have data from this region.

In this report, we primarily look at insect abundances, summarizing the results across a variety of inventory techniques. Each of the techniques we used (pit, malaise and vane traps; sweep netting; and visual observation [by Erin Allen]) has strengths and weakness, and no one technique is perfect. In part, these techniques were chosen so as to sample insects living in different portions of the habitat. Pit traps catch primarily ground-active creatures, sweep netting largely knocks organisms off of vegetation, and malaise trapping intercepts flying creatures. Vane traps were added so as to increase our bee captures, given the agroecological importance attributed to them. Erin's visual surveys also were meant to sample insects on vegetation (specifically flowers), but in a distinct way from sweep netting and were designed to provide us with added information on flower use.

We looked for patterns of consistency across results from this array of tallying techniques, giving particular weight to those relationships having or approaching statistical significance (i.e., we highlight relationships with a p value <.10). Given the relatively short duration of our monitoring – partial sampling in 2017 and full sampling in 2018, we realize that any apparent patterns should be taken with a grain of salt, to be supported, refuted or qualified in subsequent years.

Methods

Sampling Location*:* Please see the accompanying report *Native Meadow Trial at the Hudson Valley Farm Hub* by Claudia Knab-Vispo for details of the study location, plot size and design, seed mixes, meadow establishment and management, as well as a description of the vegetation development and flower abundance during the first two seasons. In brief, three treatments (a flower-rich seed mix denoted ‘A’, a more grass-rich seed mix denoted ‘B’, and an unseeded control ‘C’ otherwise managed in the same way as the seeded plots) were established organically and in triplicate, with each treatment plot being .5 acres and the total area in each treatment being 1.5 acres.

General Insect Monitoring*:* We documented the presence and abundance of insects in the experimental plots three times in 2017 (May [all traps], August [pits and sweep only], and October [pits and sweep only]) and four times in 2018 (June, July, August and September [all traps on all dates]). In each of the nine plots (three in treatment A, three in treatment B and three control) and when using a full array of traps, insects were sampled over a 24 hour period using one Malaise trap to catch flying insects; three Vane traps (two blue and one yellow) to catch insects attracted to bright, floral colors; three pit traps to catch insects walking on the ground; as well as one baited camera trap to document photographically the insects attracted to freeze-killed Fall Armyworm eggs. These were all set up more or less in the center of each plot. In addition, each experimental plot was sampled by sweep netting with a single set of 25 sweeps (to document the insects residing on vegetation); these were done roughly ¼ and ¾ of the way from a short end in order to avoid interfering with the other traps. All plots were sampled over the same periods.

We could not practically identify all captured insects to species using our visual identification techniques (gene-based ID techniques could conceivably do so). We therefore classed captures or observations into practically identifiable groups which corresponded to different taxonomic levels. These groups sometimes differed among sampling techniques, although we were able to summarize our results across techniques for comparison purposes. For example, while we did ID many of the ground beetles we captured in our pits to species in the field, in the analyses presented here, we discuss mainly ‘ground beetles’ as a group because that was the level at which malaise and vane collections were initially sorted. Likewise, we are working to identify collected bees to species, but here simply refer to them as Honey Bees (a species), bumble bees (a genus) and ‘all other bees’ (a variety of families). We have also been working to sort our wasps to family and subfamily, but in these analyses we simply settled for ‘wasp’, although we did make an effort to include even the tiniest wasps, many of which are often not recognized as such by non-entomologists. Clearly, as we look at the habitat preferences of these groups, we need to be conscious that, as now presented, they often include a variety of creatures with an array of probable habitat affinities. For example, bees with various tongue lengths will likely seek flowers with different morphologies, and ground-nesting vs. stalk-nesting bees will likely react differently to habitats with different vegetation structure. In at least some cases, we have the samples and ability to make finer distinctions, we have just not yet had the time to do so.

Monitoring of Flower-Visiting Insects*:* Flower-visiting insects were documented in the nine experimental plots every two weeks from June through September 2018 with standardized visual surveys conducted by Erin Allen as part of her graduate work at SUNY Albany. She recorded flower-visiting insects and the flower species they interacted with in 10 semi-circular samples of 2m radius distributed at even distances along a zig-zag transect within each plot. In order to evaluate the insects’ preference for certain flowers (relative to their abundance), she also ranked the abundance of all flower species present in four ranks (“1” = < 1% cover, “2” = 1 – 10% cover, “3” = 10 – 25% cover and “4” = >25% cover) within semi-circular subsamples of 1m radius embedded in the larger samples.

Erin's work also provided yet another way to look at treatment effect. Because her insects were tallied by plot, her observations could be summarized to test for differences amongst treatments in the same way as the trapping data. In addition, she conducted similar surveys in other flower-bearing habitats at the Farm Hub outside of the NMT plots.

Statistical Analyses. For each group of insects and each tallying technique, an ANOVA was used to calculate the partial squares associated with month of capture, location of capture (i.e., trial area NMT 1, 2 or 3, see *Native Meadow Trial at the Hudson Valley Farm Hub* by Claudia Knab-VispoClaudia's report) and treatment (seed mix A or B, and the control). So, for example, considering bees we ran separate tests to see if bumble bee abundance in sweep, vane, and malaise samples were significantly related to treatment, and ran two other similar sets of analyses for Honey Bees and 'other bees'. (The ANOVAs for the observation data were done without the inclusion of month or location; we plan to re-analyze them so as to include those factors, but haven't done that yet. For now, significance of observation results refers to an ANOVA by treatment only.)

Results and Discussion.

Insect Abundances in the Native Meadow Test Plots.

So, did we see major differences in the abundances of pests and beneficials among our treatments? Maybe.

The strength and statistical significance of the differences among the two seed mixes and the control varied by among insect groups considered and across census methods of census. Below, we consider the results for some of the most prominent beneficials and pests.

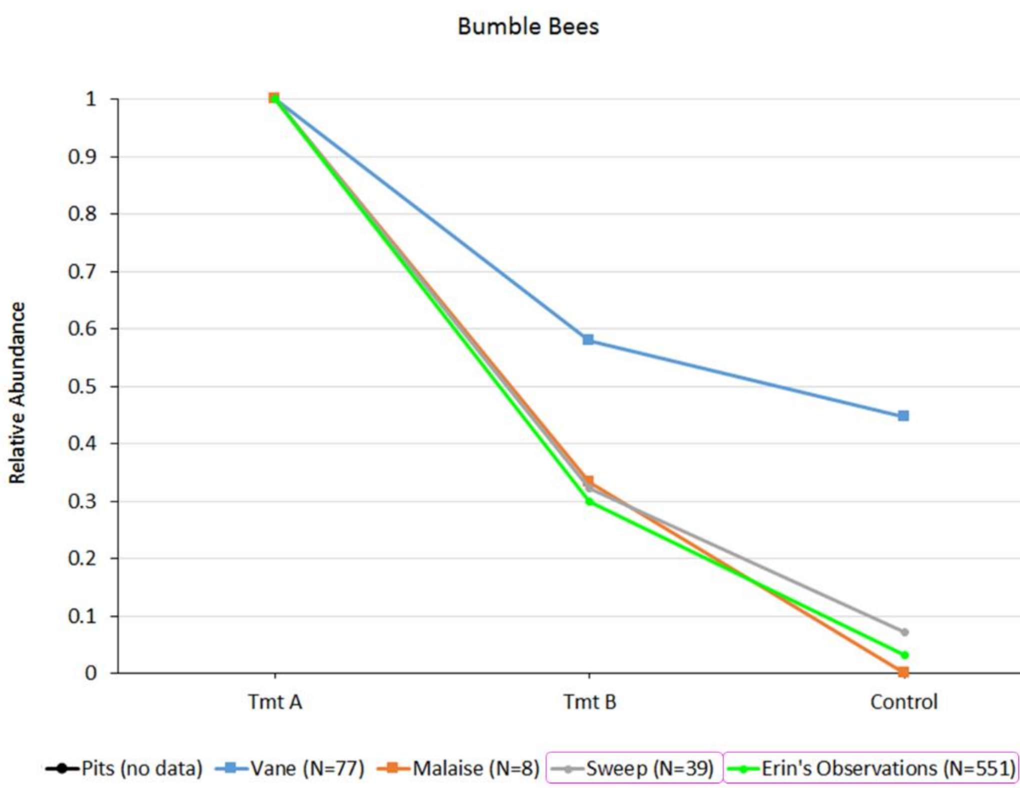


Figure 1: The relative abundance of bumble bees across our sampling techniques. In this case, no bumble bees were captured in pit traps and, as indicated by the pink-purple encircling, the patterns in the sweep catches and in Erin's observations were statistically significant at p<.10 or better. Bumble bees seemed to clearly prefer Treatment A. One would interpret this graph to say that for sweep, malaise and visual observations, bee abundance in treatment B was about 30% of that in A, while in the control it was less than 10% the abundance of A.

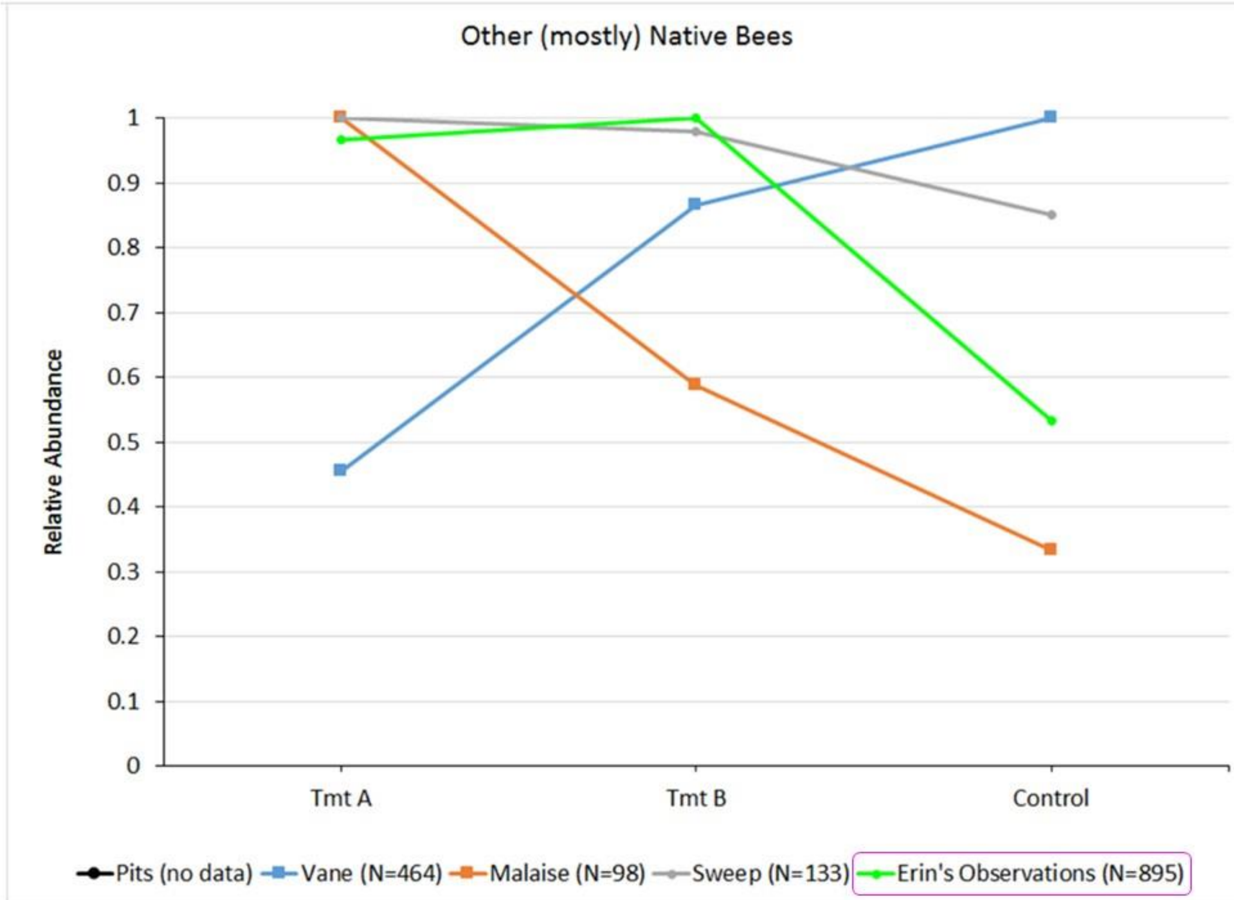


Figure 2: Records for bees other than Honey Bees and bumble bees. Only of the pattern for observations was statistically significant. If one discounts the vane trap results as reflecting the 'empty field effect', then captures seemed to be higher in the treatments than in the control. See Fig. 1 for additional graphic interpretation.

Bumble Bees. Bumble bees (Fig. 1) appeared to be most common in Treatment A. This pattern was significant in the sweep captures (and Erin's observations). Vane captures showed a similar tendency, although it was not significant. Despite our small sample sizes, the proportional consistency of the results across malaise, vane and observations is striking. As noted in the figure caption, treatment B captures for these three techniques were all around 30% of the treatment A captures, and captures in the controls were all less than 10% of treatment A values.

Honey Bees. Erin also observed significantly more Honey Bees in treatment A and B than in the controls (not shown). The patterns in the sweep and vane data were mixed, sample sizes small, and neither pattern was significant.

Other Bees. The occurrence of "other bees" (i.e., not Honey Bees or bumble bees) was mixed (Fig. 2), and only significant for Erin's observations despite moderate sample sizes from the trapping techniques. In malaise and sweep data, these bees tended to be most common in Treatment A, while in vane data, they were most common in the Control. Erin found that 'other bees' were significantly more common, in fact almost twice as common, in treatments A and B versus the control. The pattern of vane trap results appeared to run counter to those of the other methods. This may not be surprising – vane traps are big and colorful, they are essentially visual bait. In a plot full of colorful, tempting flowers, vane traps may hold relatively little attraction. However, in a drabber plot (such as the controls), their color probably stands out, and their draw is thus enhanced. Sam Droege, a noted bee expert, calls this the “empty field effect”.

Treatment A abounded in large, sometimes deep-flowered plant species. These seemed to be favored by bumble bees and Honey Bees but smaller bees may have found less to distinguish the treatments from the controls where the small-flowered Horseweed was common at least later in the summer.

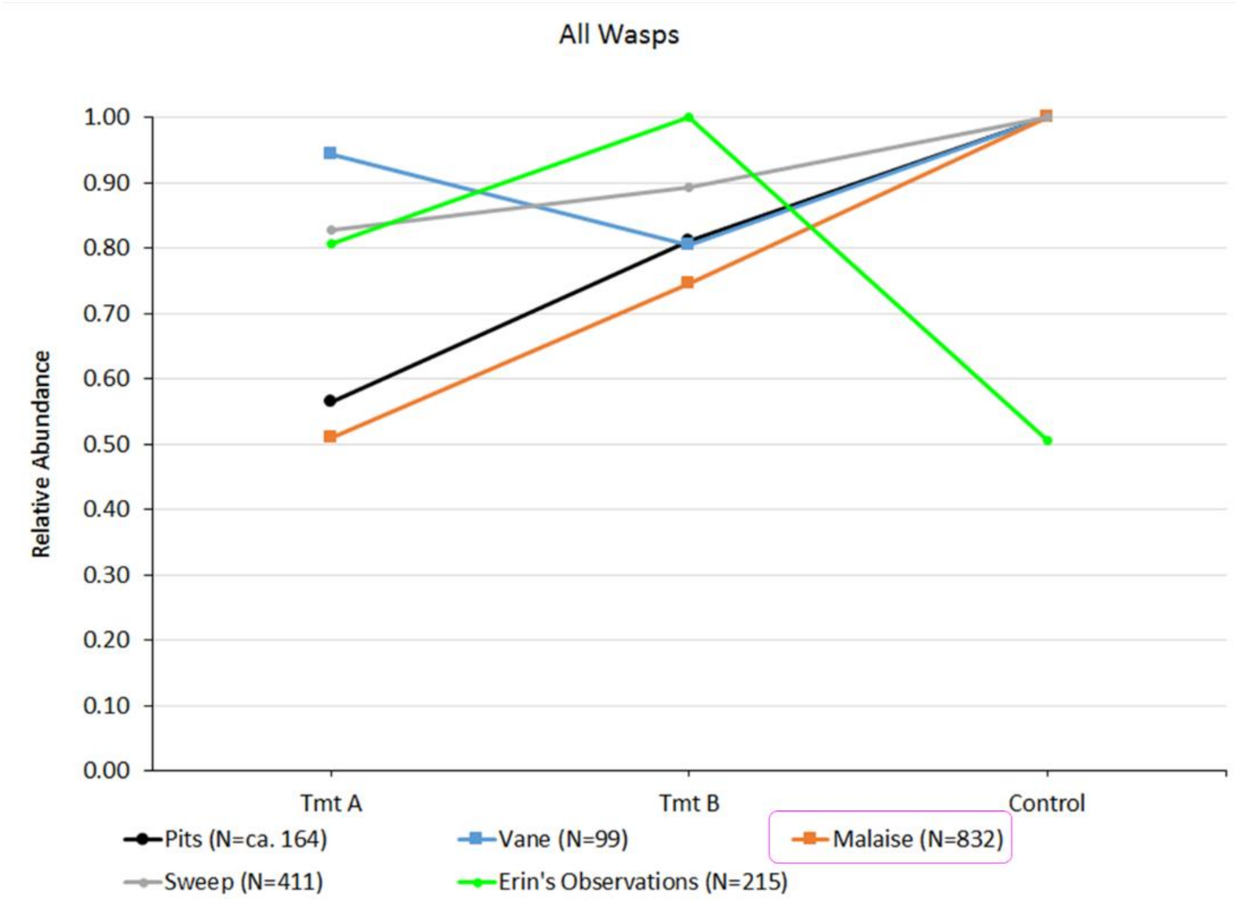


Figure 3. The relative abundance of wasps in captures and observations. Other than in Erin’s observations (which may reflect the difficulty of seeing wasps in the tall vegetation that came to dominate the controls), wasps were most common in the control, and the pattern was statistically significant in malaise captures. See Fig. 1 for additional graphic interpretation.

Wasps. In our samples, we classified wasps according to size as “macro”, “medio” and “micro”. These are admittedly somewhat subjective, and the great majority of our wasps were classified as “micro”. For this reason, plus the fact that some larger wasps can also be “beneficial”, we lumped all wasps into a single category. If anything, wasps appeared to favor the controls (Fig. 3). This relationship was significant in the malaise samples (where we caught the most wasps) and present, but not statistically significant in the sweep data. There were almost twice as many malaise captures in the control as in treatment A. The vane data and Erin’s observations did not show clear patterns. Because many of our wasps are tiny and have short tongues, we believe that their use of the controls may have partially reflected the previously-mentioned abundance of Horseweed in these plots (see below for wasp flower use). However, month-by-month analysis suggests that, at least in the malaise data, wasps were already more abundant in controls during June. This was before Horseweed was in full flower, and may suggest that other factors were also drawing wasps to the control.

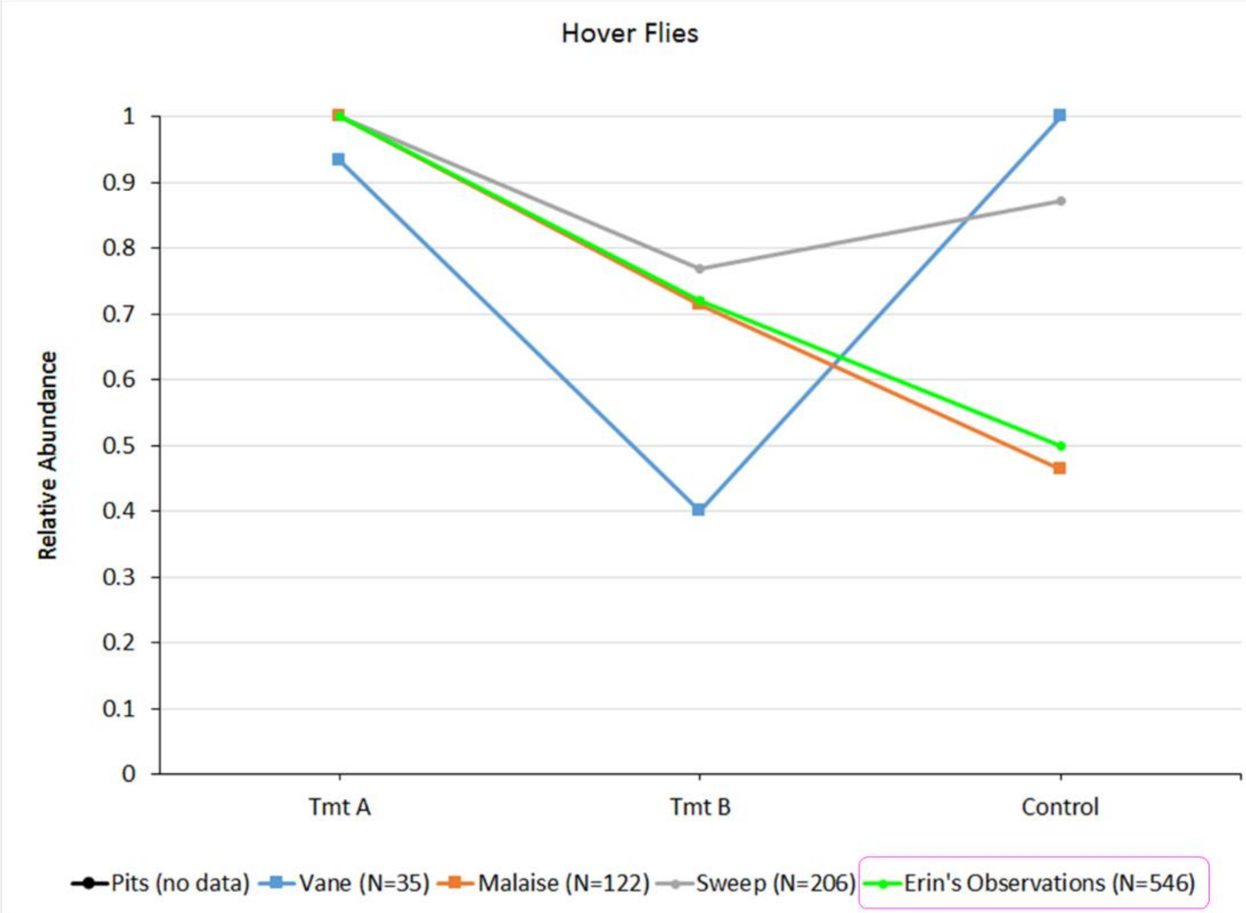


Figure 4: Relative hover fly observations and captures. Vane trap captures may reflect the "empty field effect", but otherwise hover flies were most common in Treatment A. See Fig. 1 for additional graphic interpretation.

Hover Flies. None of our trapping methods indicated a significant relationship between hover flies and the treatments, although in Erin's data they were clearly more active in Treatment A where she observed about twice as many as in the control (Fig. 4). This pattern was duplicated almost exactly in the malaise data, although, as stated, this was not statistically significant. At this time, it is difficult to know what patterns, if any, existed in actual hover fly abundance. The patterns in Erin's visual observations seem relatively strong, but hover flies may have been more conspicuous in the seeded treatments as they perched on the large individual flowers. If the real pattern were as marked as Erin's observations suggest, it is surprising that the sweep data, with a relatively robust sample size, did not reflect it. Dylan Cipkowski, in his work at Hawthorne Valley Farm, has found that hover fly populations were significantly lower in plots from which he removed the most common flowers. Clearly, many hover flies use flowers, but we are still uncertain what role wild flower plantings can play in shaping their abundance patterns.

Tachnids and Long-legged Flies were distinguished and tallied in malaise captures, but, despite decent sample sizes, showed no significant patterns between the treatments.

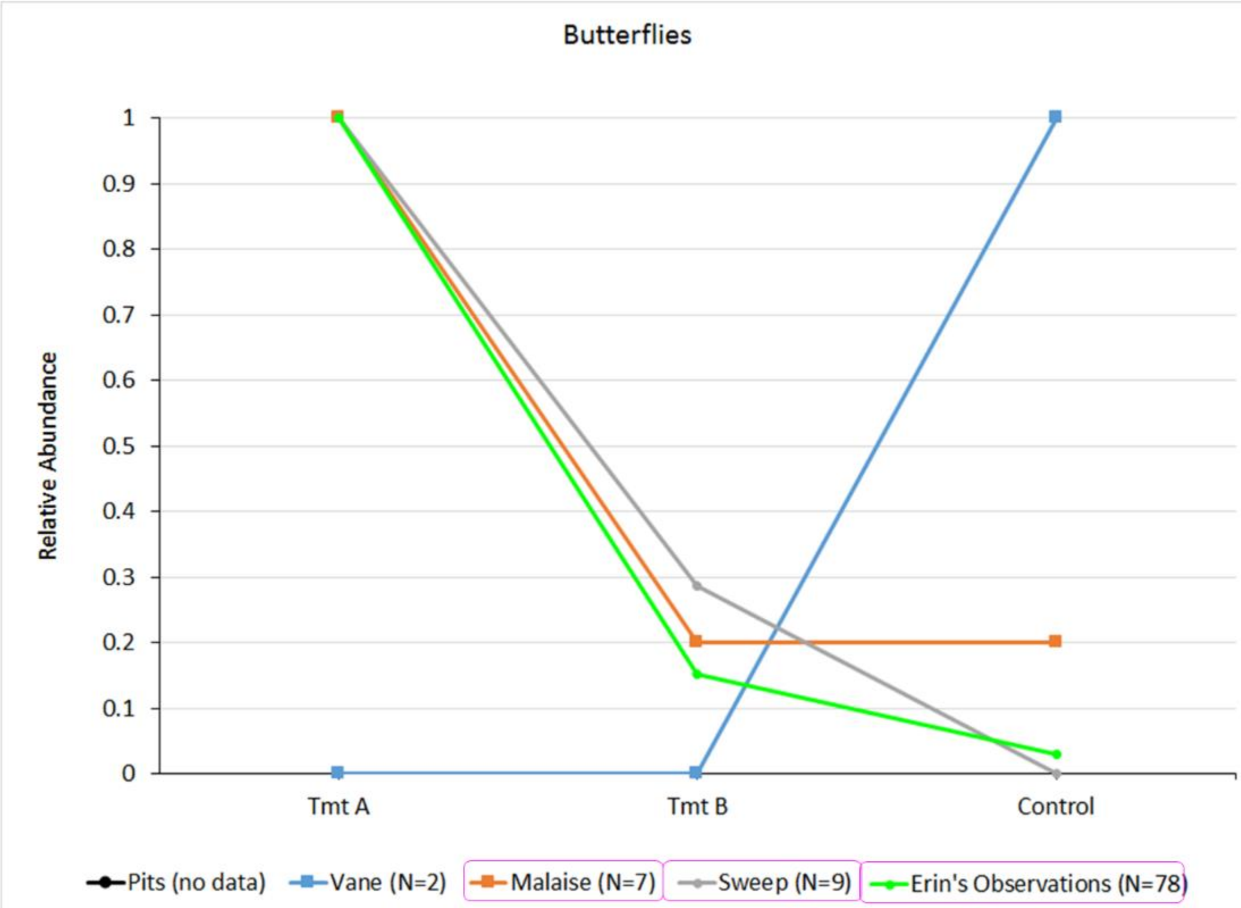


Figure 5: Relative butterfly captures and observations. Sample sizes are generally small but for malaise and sweep captures and visual observations, they were statistically significant and consistent in showing peak numbers in Treatment A. See Fig. 1 for additional graphic interpretation.

Butterflies. Butterflies were rare in all our captures, not because they were actually rare, but because our trapping techniques did not work well to collect them. Nonetheless, Treatment A appeared to hold more butterflies than Treatment B and the Control (Fig. 5). In fact, Erin observed more than twenty times as many butterflies in Treatment A as in the Control and about five times as many in treatment A vs B. Similar ratios seemed to hold for malaise and sweep captures, and vane captures were trivially small. Butterflies, like many bumble bees, are probably well-adapted to the large, sometimes deep, flowers that were most common in Treatment A.

Ground Beetles. Ground beetles (not shown) were primarily captured in pit traps, although, during dispersal, flying species also appeared in some of our other traps. There was no clear or significant relationships with treatment, nor, for that matter, with trial area (i.e., NMT 1, 2, or 3). This is not particularly surprising as one might expect ground beetles to respond more to soil conditions (which, as indicated in *Native Meadow Trial at the Hudson Valley Farm Hub* by Claudia Knab-Vispo, showed little difference across treatments) and generalized cover than to flower abundance. Data for a few of the most common individual species also showed no apparent patterns related to treatments.

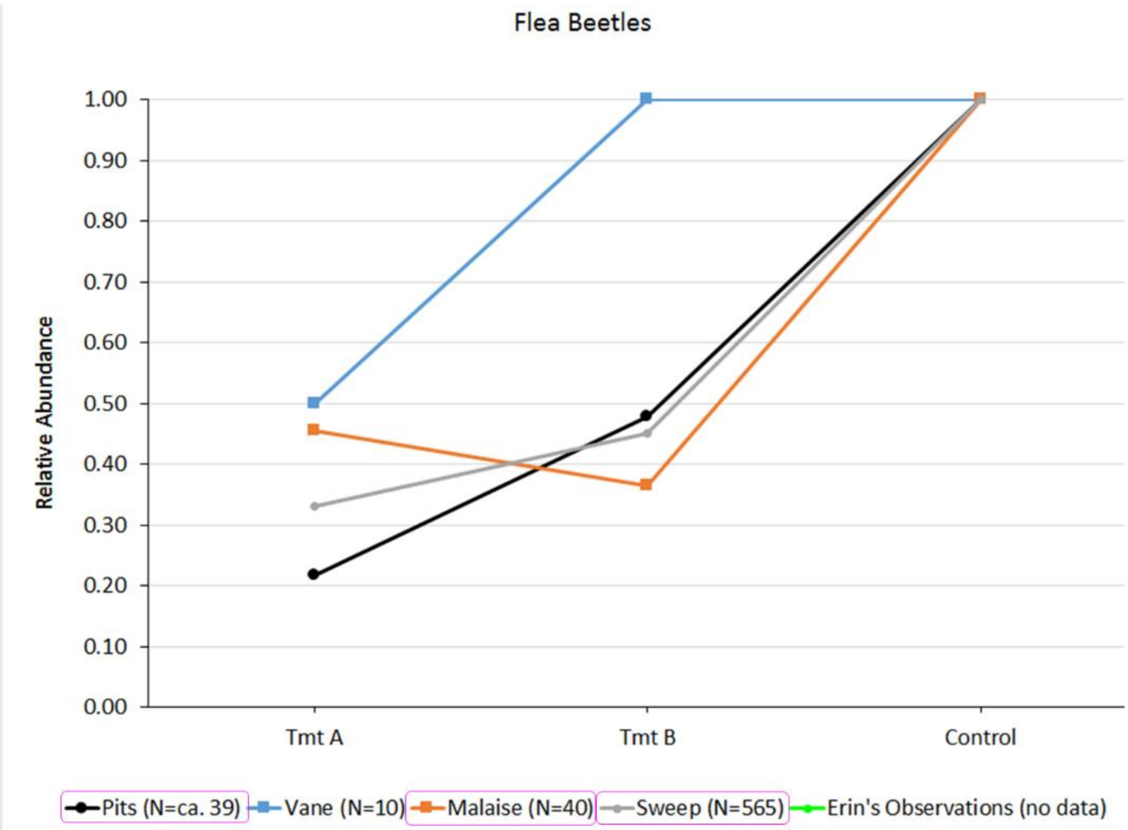


Figure 6: Relative captures of flea beetles. The patterns in pit, malaise and sweep trap captures were significant and consistent in showing flea beetles to be most common in the control. See Fig. 1 for additional graphic interpretation.

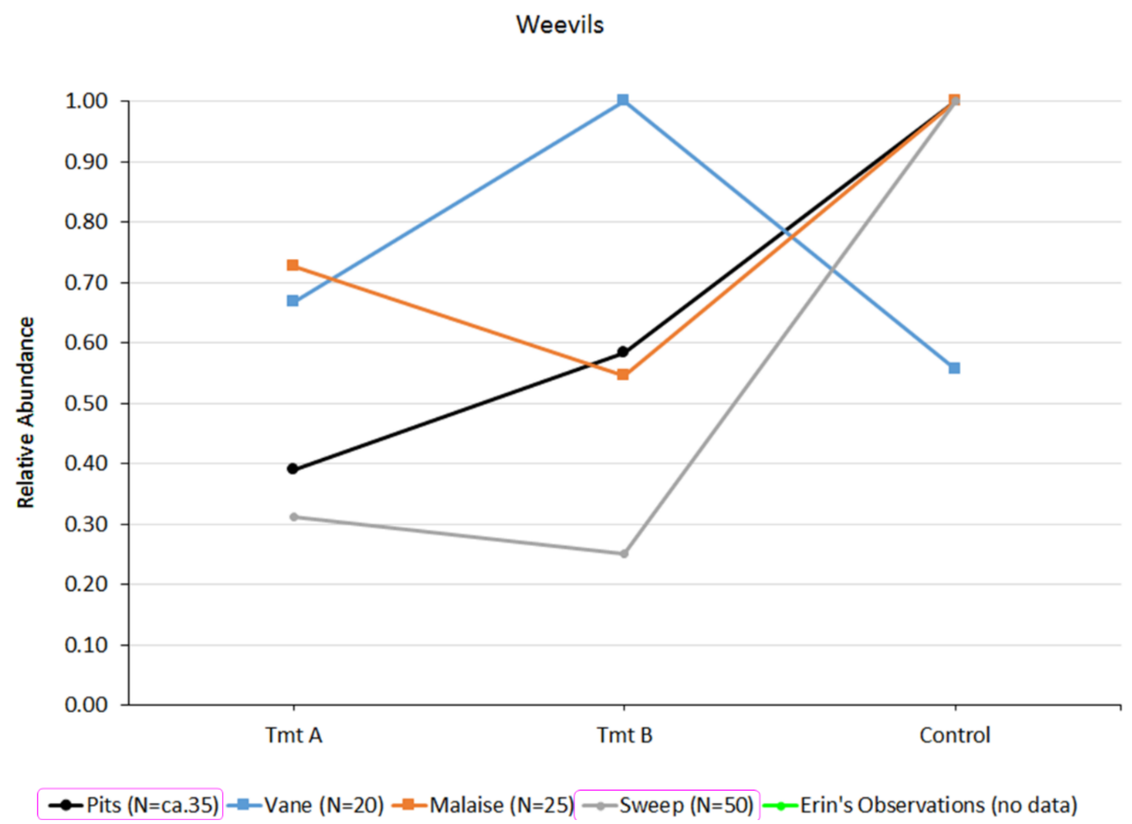


Figure 7: Relative captures of weevils. The patterns in pit and sweep trap captures were significant and consistent in showing weevils to be most common in the control. See Fig. 1 for additional graphic interpretation.

Other Beetles. Lady beetles, click beetles and rove beetles (not shown) also demonstrated no clear relationship to treatment, whereas two notable beetle pests – flea beetles and weevils – seemed to be distinctly more common in the control plots. For flea beetles (Fig. 6), malaise, sweep and pit captures were all higher in the controls with abundances being two to four times those of the treatments; for weevils (Fig. 7), captures in pits, malaise, and sweep were all highest in the control. There was a hint in our data that different patterns may hold for other beetles. Beetles belonging to types other than those we tallied individually (i.e., our "other beetle" category) tended to be most common in treatment A. If this pattern continues to hold, we should try to better determine what sorts of beetles are responsible for it. Many may be *Stilbus* or related tiny members of the shining flower beetle family. Adults reportedly consume Compositae pollen, and so may have been attracted to seed mix A, which had the highest diversity and abundance of such flowers. These beetles may also consume plant-disease-causing fungi.

Ants. Ants are relatively rare at the Hub (not shown). Sweep net samples (while accounting for 26 captures) were significantly more common, indeed at least three times more common, in treatment A than in the other treatments. However, our more numerous pit captures (N=192) showed no such pattern. It may be that ants were more apt to climb up into the vegetation when the large flowers were present and so, even though not actually any more common, were more apt to be caught in sweep nets in Treatment A.

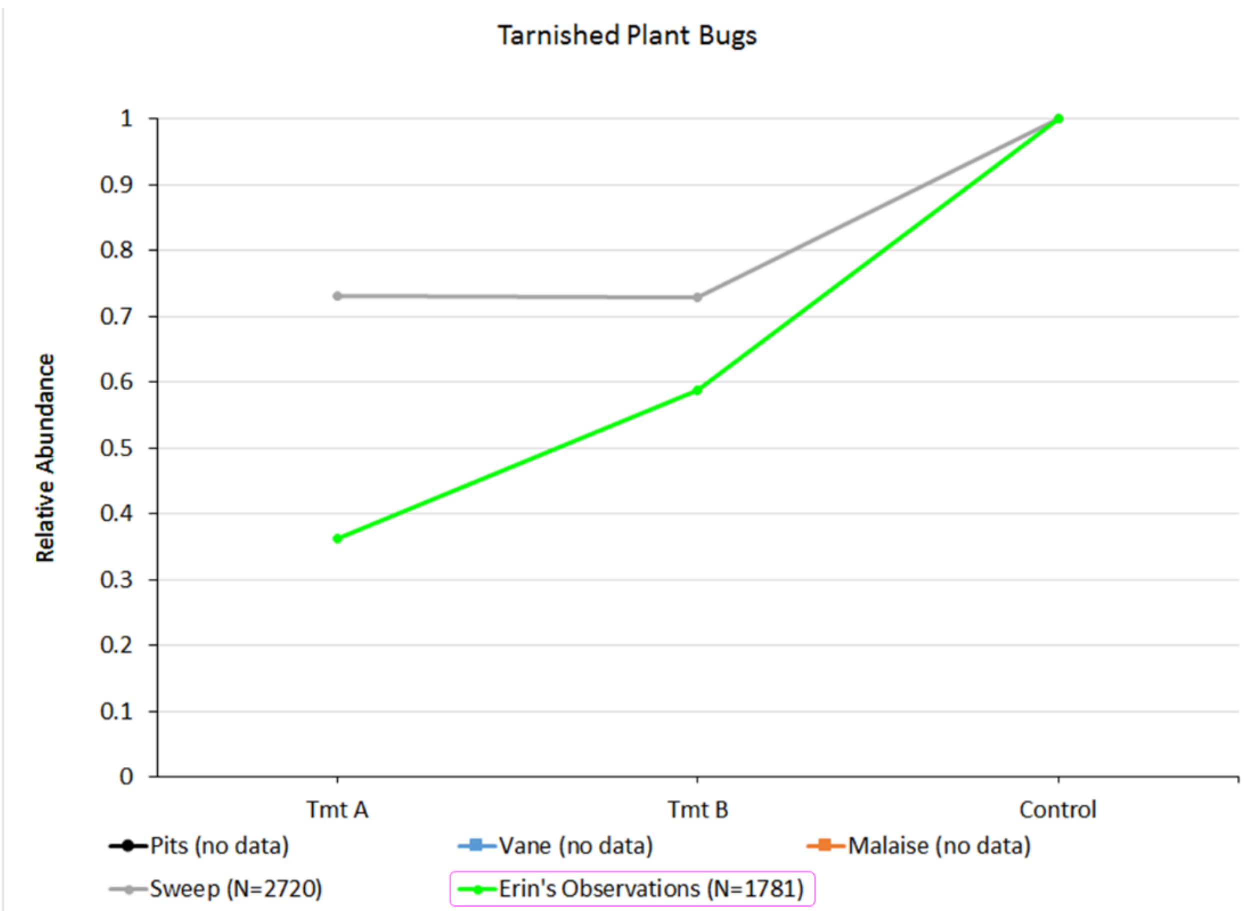


Figure 8: Tarnished Plant Bugs were only recorded in Erin's visual observations and sweep netting, and only statistically significant in the former. Both techniques showed relative abundance peaking in the control. See Fig. 1 for additional graphic interpretation.

Tarnished Plant Bugs, Aphids, Leafhoppers, and Other True Bugs. Tarnished Plant Bugs were only recorded for sweep catches and visual observations (Fig. 8). In both cases, occurrence was higher, by at least 30%, in the control. However, the pattern was only significant for Erin's observations. Despite relatively large sample sizes, no clear patterns were evident in the captures of aphids, leafhoppers, or 'other true bugs' (not shown).

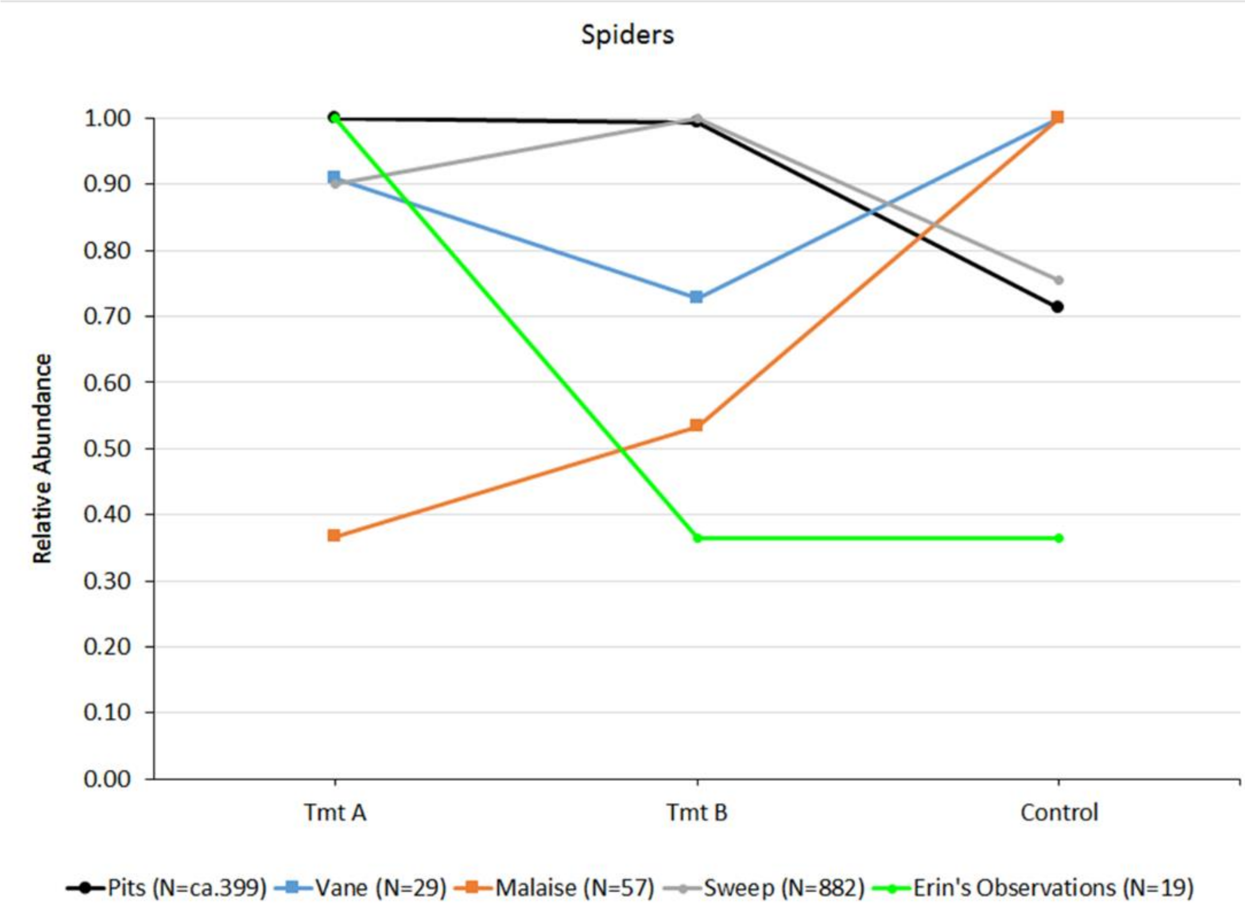


Fig. 9. Spider abundance by survey technique and treatment. None of the patterns were statistically significant. See Fig. 1 for additional graphic interpretation.

Spiders. Despite some relatively high sample sizes, no clear or significant patterns of spider abundance were found in our data. While this may reflect slop in the data, it may also reflect the fact that "spiders" encompasses a wide variety of organisms with a diversity of life styles. For example, pit traps caught primarily the ground-active wolf spiders, sweep netting gathered climbing spiders (such as crab and jumping spiders) from flowers and other vegetation, while malaise and vane traps may have been more likely to intercept young, ballooning spiders from a range of families. In other words, the unclear patterns may indicate the need for refining our taxonomic focus.

Table 1: Table summarizing our results. Treatment A seemed to favor certain beneficials, the control favored wasps and three pest groups, while the patterns associated with several other groups were unclear.

Treatment A	**Control**	**Mixed/Unclear**
Bumble Bees	Wasps	"Other" Bees
Hover Flies?	Weevils	Lady Beetles
Butterflies	Flea Beetles	Spiders
	Tarnished Plant Bugs	Ground Beetles (not shown)
		Leafhoppers

In sum (Table 1), the flower-heavy treatment A favored some, but certainly not all beneficials, while some but not all pest groups studied were most common in the control. Our results would suggest that increasing the abundance of showy flowers is but one ingredient in creating habitat to support beneficials. This result is consistent with our previous studies which suggest that different forms of naturally-occurring or unintentional semi-natural habitats around farms are necessary for supporting a full suite of beneficials.

Flower Preferences.

Can we better understand why we are seeing the patterns of insect occurrence described above? One possible explanation is that different insects favor different flowers which, in turn, were associated with different treatments. Through Erin Allen's observational work, we can address this possibility directly, and we do so by looking at the flower preferences in two of our insect groups, bumble bees and wasps, which differed in their treatment preferences.

Bumble bees (Fig. 10) seemed to favor the large, showy flowers, such as Black-eyed Susan, Monarda and New England Aster, which were common in treatment A. Many of these are relatively deep flowers, whose nectar is accessible to the long tongues of many bumble bees. In contrast, while Black-eyed Susan was also attractive to wasps (Fig. 11), unseeded species such as Annual Fleabane, Horseweed and Queen Anne's Lace were also important. Horseweed was at least 10x more abundant in the control than in treatment A, and wasp preference for this species may help explain their apparent abundance in the controls.

Such differences in flower preferences may help explain the observed differences in bumble bee and wasp occurrences. However, these are only correlations and do not necessarily show cause and effect. For example, wasps could favor the control for reasons unrelated to flower composition and then, because of that independent preference, incidentally land commonly on Horseweed. We evaluated this possibility by looking at Erin's data from *outside* of the NMTs.

As these data (Table 2) show, a marked difference was still apparent in the flowers visited by bumble bees and wasps, with wasps apparently preferring shallower flowers (such as the fleabanes, Queen Anne's Lace and Yarrow), as was the case in the NMT data. (Note that Horseweed was rare in the non-NMT areas that Erin surveyed, and so we could not evaluate wasp taste for this flower independent of the NMTs.)

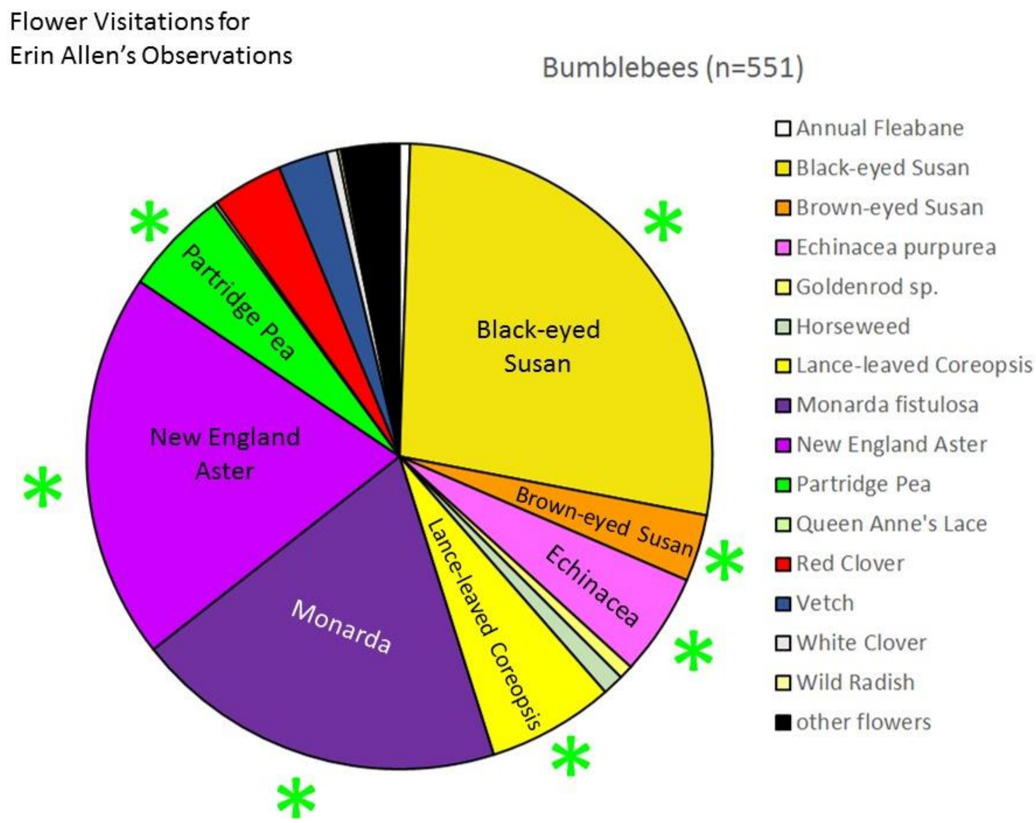


Fig. 10. The species composition of the flowers upon which bumble bees were observed in the Native Meadow Test Plots. Green asterisks indicate species that were intentionally planted in the NMTs.

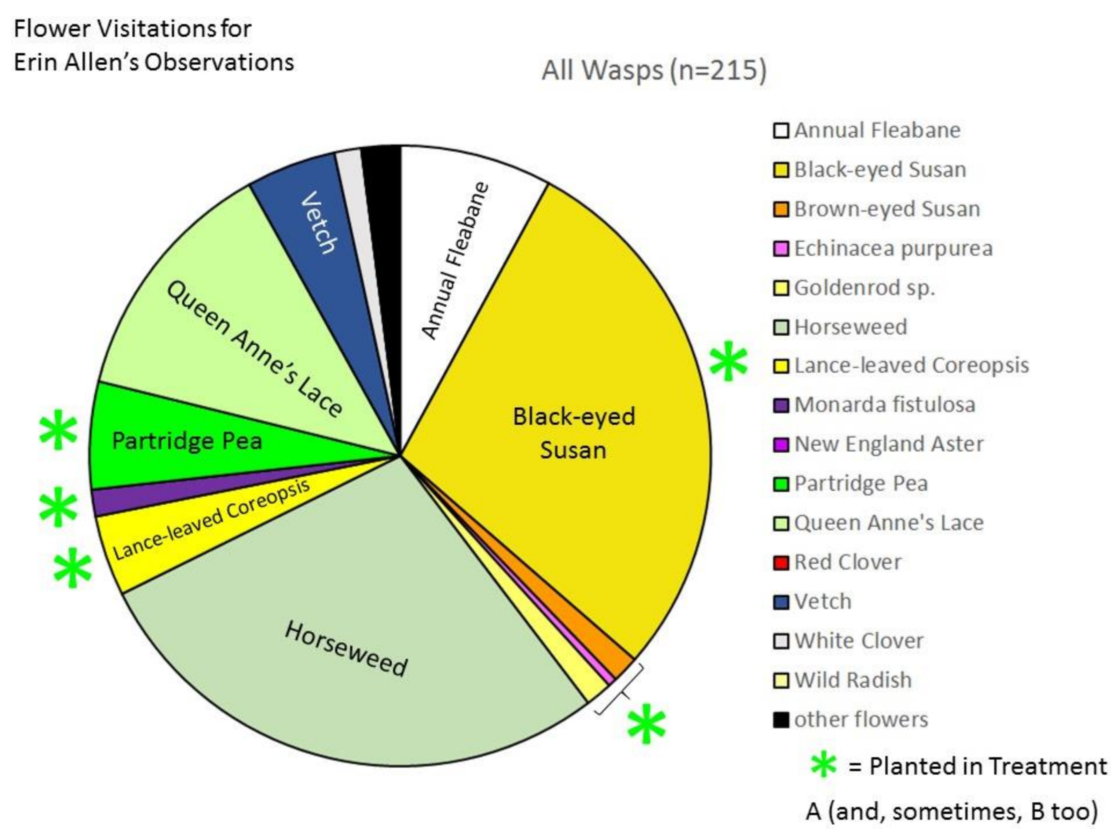


Figure 11. The species composition of the flowers upon which wasps were observed in the Native Meadow Test Plots. Green asterisks indicate species that were intentionally planted in the NMTs.

Table 2. The top flowers accounting for ca. 75% of all observed flower visits at the Hub by wasps and bumble bees outside of the Native Meadow Test plots according to Erin Allen's data. Only goldenrods were shared favorites.

Bumble Bee (N=933)	Smaller Wasps (N=164)
Anise hyssop	Annual fleabane
Aster sp. (Calico aster?)	Canadian Thistle
Carey's smartweed	Creeping buttercup
Celosia	Goldenrod sp.
Chicory	Philadelphia Fleabane
Clary sage	Queen Anne's Lace
Echinacea	Spearmint
Goldenrod sp.	Yarrow
Purple stem beggarstick	
Sunflower sp.	
V. villosa	
White Clover	
Zinnia	

While these data do not prove that the differences we saw in insect abundance between the NMT treatments were due to flower abundances, they are highly suggestive of this.

An Alternative Control Treatment.

The control incorporated into the NMT study is essentially a fallow field managed following the same general protocols as the seeded plots minus, of course, the seeding. For example, it is cut only when the treatment A and B plots are cut, and weeding activities applied to A and B are also applied to the control.

An alternative control perhaps more representative of what a farmer might actually do if they did not plant a native meadow might be reflected by the management applied to field 8, an expansive field planted in a standard hay mix (Orchard Grass, Rye Grass and White Clover) and adjacent to all three of the NMT locations. While no intentional control under such management was included in the NMT study, field 8 is included in our long-term insect monitoring which uses survey techniques identical to those applied in the NMT plots (minus Erin's direct observations). While not done on exactly the same dates as the NMT sampling, in 2018 field 8 sampling did occur in at least the same month as the June and July NMT sampling. In the long-term insect monitoring, sampling points were placed at the edge of the field, 300' into the field, and 600' into the field. To compare field 8 results to the NMT sampling, field 8 captures of spiders, bees, microwasps, lady beetles and hover flies (for malaise, vane and sweep trapping) and ground beetle, rove beetle, ants, and spiders (for the pits) at these three points were averaged and then compared to the corresponding captures in the NMT study. Comparisons were done for all four trapping methods and for both months. The results are summarized in Table 3 wherein the captures by taxa and trapping method were compared among the three NMT treatments and field 8, and the locations having the highest and lowest values were recorded for each comparison.

Field 8 had the highest number of peak captures (18) and the second to lowest number of low captures (12). Treatments B and A had the lowest number of peak captures, while the NMT control had the largest number of low captures. In at least half the comparisons, spiders, bees, wasps and lady beetles were most common in field 8; only hover flies seemed unimpressed, being most common in treatment A instead. The comparison is crude and the standardization imperfect, but these results suggest that inclusion of a control more similar to a farmer's likely alternative management might be important.

Table 3. Comparison of the field 8 'control' to insect captures in the NMT plots. For June and July 2018, captures in pit, vane and malaise traps and in sweeps were compared for select insect groups. For each set of comparions (i.e., each month, taxon, method combination) highest and lowest capture locations were identified, and those are tallied in this table. In a few cases there were ties, and so the highest or lowest honors were assigned to more than one location. See text for details.

	Highest Captures	Lowest Captures
Field 8	18	12
NMT Control	10	15
Tmt B	4	3
Tmt A	7	13

Response to Sentinel Bait.

Finally, we have one more set of data with which to evaluate the difference among the treatments: our camera data. Did visits to our Fall Armyworm egg bait differ among treatments? While we cannot yet explain the differences, Fig. 12 suggests that they existed. For example, baits in treatment A saw the most visits by ants, lady beetles, and true bugs; treatment B baits had the highest visits by ground beetles, slugs and daddy longlegs; and the control baits had the highest visitation by crickets and spiders (although treatment A was a close second). Interestingly, although sample sizes were small for some of these taxa, abundances in pit trap captures appeared to show patterns that diverged from our bait tallies. For example, ants were slightly *more* abundant in treatment B than in treatment A, while ground beetles were somewhat *more* common in A than in B; this is the reverse of the pattern seen in the camera data and appears to illustrate the importance of indexing services directly and not just relying on abundance data as a proxy.

Conclusions.

With but one year of data, all our conclusions must still be very preliminary. Differences in surface conditions, for example, are likely to take time to develop, and we might expect that ground faunas will diverge more than they already have. Bee, butterfly, wasp and perhaps hover fly occurrence appear to show some patterns; further data will either strengthen or weaken our confidence in those. Results to date are cautiously encouraging. They show that some insects considered to be beneficials are responding to our treatments. At the same time, they point out the apparent difficulty of satisfying all beneficials, and suggest potential ways of improving our seed mixes (e.g., including more shallow flowers so as to attract more wasps).

That said, we need to be careful not to place too much weight on these results, not only because of their still-short duration, but also because abundance doesn't necessarily translate into services. While the categories of "beneficial" and "pest" can be useful, they may often be too imprecise to allow accurate prediction of actual consequences for commercial production. In part, this is because it is not often clear what the unit of beneficial worker or pest actor is – how does one weigh, for example, the occurrence of 10 parasitic wasps against that of 100 Tarnished Plant Bugs? Furthermore, not only insect action in relationship to the crop plant is important but so too is reaction to habitat. For example, does good habitat attract and hold an insect and discourage it from roaming into crops (e.g., a 'trap crop' in the context of pests), or does it provide for populations that then overflow into adjacent crops, benefitting or damaging them as the case may be?

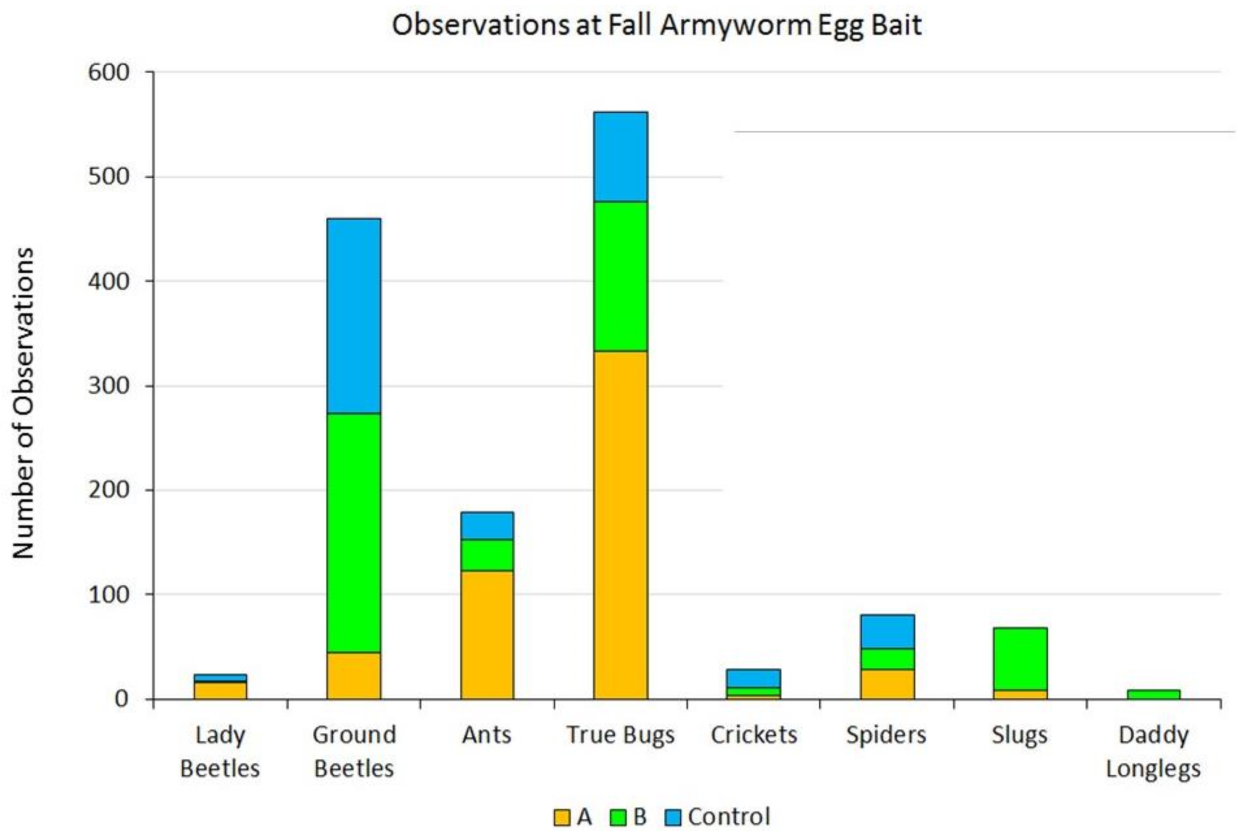


Figure 12. Number of observations of select apparent predators at bait stations. Total observations during 24 hours of time-lapse photography (photos taken every 5 minutes) are shown. Ground beetles and true bugs were the most common visitors to the baits.

It seems crucial to seek additional ways of understanding the services that beneficial insects are providing and to assess the *net* effects of habitats on adjacent crops. The following three approaches seem at least theoretically possible:

1) Expand our use of sentinel baits from Fall Armyworm eggs on the ground to caterpillars or other baits, and to plant leaves or other locations. None of these would provide perfect results, but they would help paint the picture.

2) Use DNA analyses of gut contents to better understand what generalist predators are eating. For example, can we document what the numerous ground beetles at the Farm Hub are actually consuming? This won't translate directly into a crop effect, but if done across the season and across crops could give us a much deeper understanding of the role of these creatures.

3) Plant sentinel crops beside the native meadow treatments and document crop health and productivity. We could, for example, plant strawberries or some other crop beside our NMT plots, and then classify and tally pest damage, gauge pollination, and record yield while simultaneously continuing to tally insect abundances.

None of these approaches will provide us with final answers, but each could markedly improve our current grasp of cropfield insect ecology.

C. Vispo, 13 March 2019

Interim Farm Hub Long-term Monitoring Insect Report

In 2016, we began long-term invertebrate (from hereon called “insect”, but does include non-insects such as spiders) monitoring of three fields at the Farm Hub. The goal of this work is two-fold:

- To provide data that can contribute information on long-term insect population trends as a reflection of Farm Hub practices and larger regional trends. We will not be able to immediately tease apart these influences, and they could well interact, but we should be able to detect dramatic changes.

- To gather data on the patterns in insect occurrence from field edge to center. Some insects rely on woodland areas and/or shrubby edges for resources during parts of their life cycles; other species seem to have little need for such habitats. Our transects allow us to start describing edge-to-center patterns.

Recently, there have been several reports of global insect declines. These have focused attention on the possibility that we are experiencing dramatic but heretofore largely unheralded declines in insect abundances. To my knowledge, there are few long-term insect monitoring sites on the Hudson Valley (Fourth of July Butterfly counts being a notable exception). In addition, the Farm Hub has been transitioning from conventional to organic management and using soil building techniques to enhance soil life. Such changes might be expected favor insect populations. While these co-occurring forces at various scales can be hard to isolate, long-term monitoring will at least help us discern trends, even if explaining those trends is not always straightforward.

There is published research looking at how beneficial and pest insect abundances vary with distance from wilder habitats. However, most of this work has been done with perennial crops (e.g., in orchards and vineyards) and/or in landscapes distinct from the Hudson Valley. As our own previous work has indicated, one can imagine that insect communities occurring across wild-to-cultivated transitions are composed of three groups of organisms grossly defined by their habitats: 1) those which are more or less confined to the wilder habitats; 2) those which occur across both the wild and cultivated habitats; and 3) those more or less confined to the cultivated habitats. It is the second group of insects which interest us most from an agronomic perspective, because these are the ones most likely to be affected by the inclusion of non-crop habitats. These distributions likely reflect ecological requirements. For example, woodland bees seem to be predominantly small and nest in cavities, field bees are often ground nesters, and woodland-and-field bees include large cavity/ground nesters like bumble bees which may nest in wilder habitats but forage far into fields. Our on-going Hudson Valley work seeks to combine general information on the distributions of various classes of pests and beneficials from field edge to field center with more detailed work to describe the taxonomy and hence ecology of the various insect groups involved.

Methods

In 2016, standard monitoring occurred in fields 8, 10 and 15. In 2017, in a perhaps futile effort to insure we included a vegetable field in our monitoring (and to enhance practicality), field 15 was replaced by field 19. In 2018, sampling continued in fields 8, 10 and 19, and current plans are to maintain that sampling regime despite the possible removal of field 19 from the vegetable rotation. In each field during each year sampling was conducted within about 20’ of the field edge, at 300’ feet into the field from the edge trap and at 600’ into the field.

Sampling technique parallels the methodology we have employed in the Native Meadow Test Plots (see that report)– a vertically stratified sampling which uses pit traps to capture ground-surface dwellers, sweep netting to knock creatures off of vegetation, malaise traps to intercept flying or drifting insects, vane traps to get more detailed information on bees, and close-focusing time-lapse cameras to index predation pressure at a bait.

Sampling in 2016 differed slightly from that in subsequent years. It included bat and moth monitoring, but limited malaise trapping to the daylight period and focused on overnight, rather than 24-hour, pit trapping. These differences should not affect relative captures across distances, but complicate comparisons of 2016 absolute value with those of subsequent years. For these reasons, only sweep netting absolute values are compared across all years.

A multifactorial ANOVA was used to tease apart associations with month, field and distance-into-the- field. Partial squares estimated the amount of capture variation associated with each variable after the remaining variables were accounted for.

Results and Discussion.

For most organisms (see Figs. 1a-c), it is difficult to see distinct and consistent (across methods) edge-to-field-center patterns. Several groups (rove beetles, leafhoppers, hover flies and flea beetles) had modest tendencies to be more common towards the field center, while bees, ants, and weevils had hints of edge preference. In some cases, for some techniques, the patterns are statistically significant, but there is little consistence across techniques and, at this point, I would say the pattern is more one of homogeneity than strong gradients.

There are several possible explanations for this lack of obvious patterning aside from the possibility that, in fact, it often does not exist. First, by grouping multiple species into large taxa, we have lost species-level information. For example, while wasps in general may show no obvious preference for edge or for field center, most individual species may, in fact, have preferences, but they are obscured when all species are lumped together. We are working to refine our taxonomy for some groups. Secondly, we are still trying to understand why the results of different techniques sometimes vary dramatically for the same taxa. In some cases, it may reflect how the given technique interacts with the surrounding habitats, for example and as noted in our report on the native meadow test plots, vane traps sometimes exhibit the 'empty field effect' meaning that they actually have higher captures where there are fewer flowers to compete with the visual bait of the vane traps themselves. Thirdly, different traps may capture different taxonomic subsets of the species groups; for example, malaise and vane traps may be catching ballooning spiders whereas pit traps are mainly capturing wolf spiders. Last but not least, the fields we sampled in were active farm fields whose management was largely beyond our control. Use was not always uniform across these fields and so, in some cases, agricultural habitats farther into the field may have differed in their appeal from those at the edge, confounding any distant effects.

In these graphics we have not presented forest data from 2016 when we also sampled just inside of the forest edge. There were technical challenges to this work (think sweep netting in rose bushes), but those results did suggest some dramatic differences between forest and field in some cases. We are considering to re-introduce forest sampling in 2019.

Lastly, the other goal of this monitoring, aside from looking at edge-to-center effects, is long-term changes in the insect communities. Three years of sampling is not 'long-term'. In addition, because of some inconsistencies during our first year of sampling, the most easy-to-compare data come from the sweep nets. Fig. 2 shows the absolute captures from our sweep across the three years. This graph is useful not because it can tell us anything about long term trends, but because it demonstrates the typical large inter-year variation in captures. Notice, for example, the 2017 burst of micro flies and the 2018 jump in aphids. Climate, predator abundance, field management, and natural cycles may all contribute to such variation. It is this type of 'noise' that makes detecting long-term trends so difficult and the collection from multiple years so important.

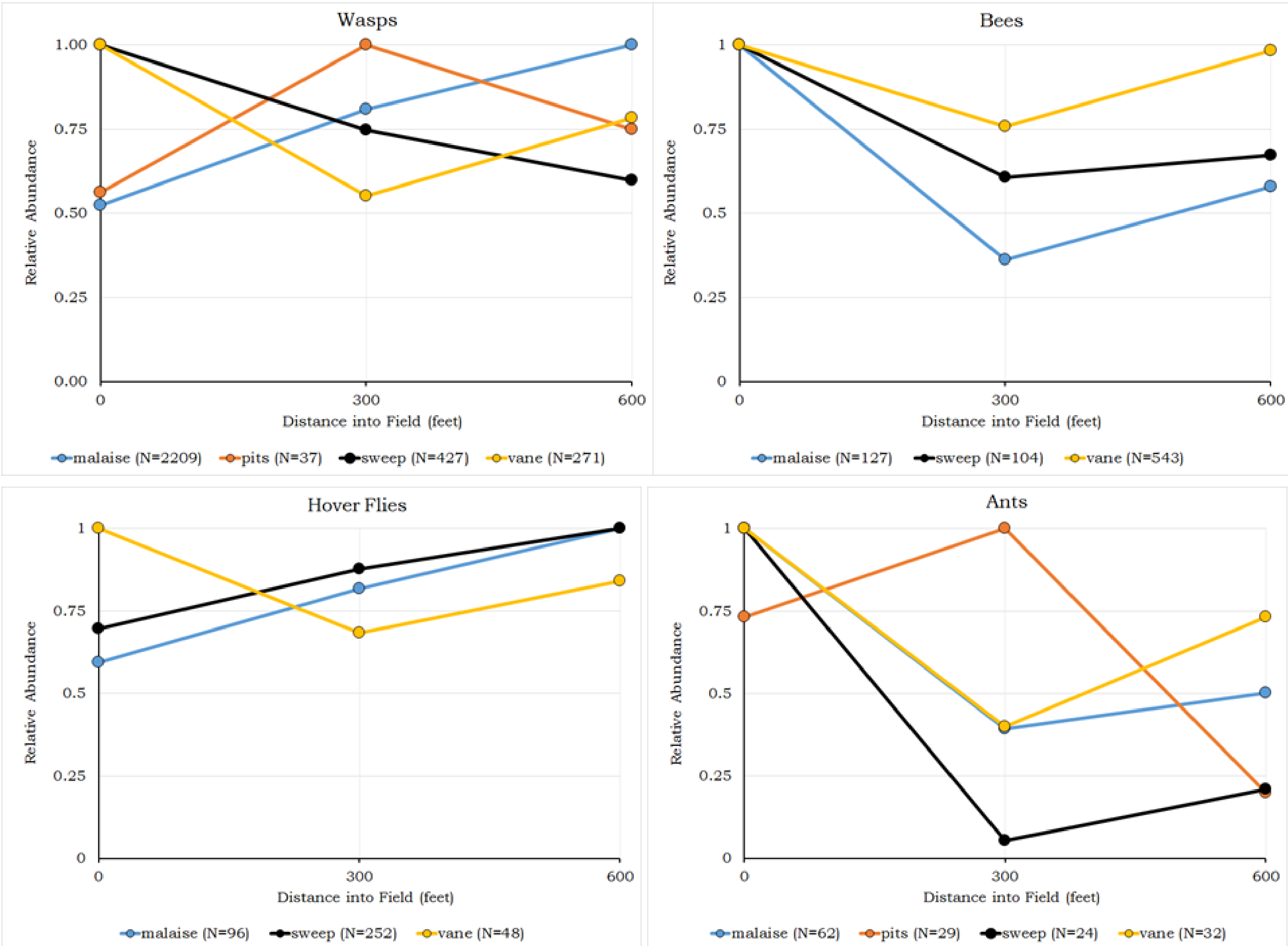


Fig. 1a. Relative abundance of wasps, bees, hover flies and ants across three different distances and four different sampling techniques (few if any bees and hover flies were captured in pit traps).

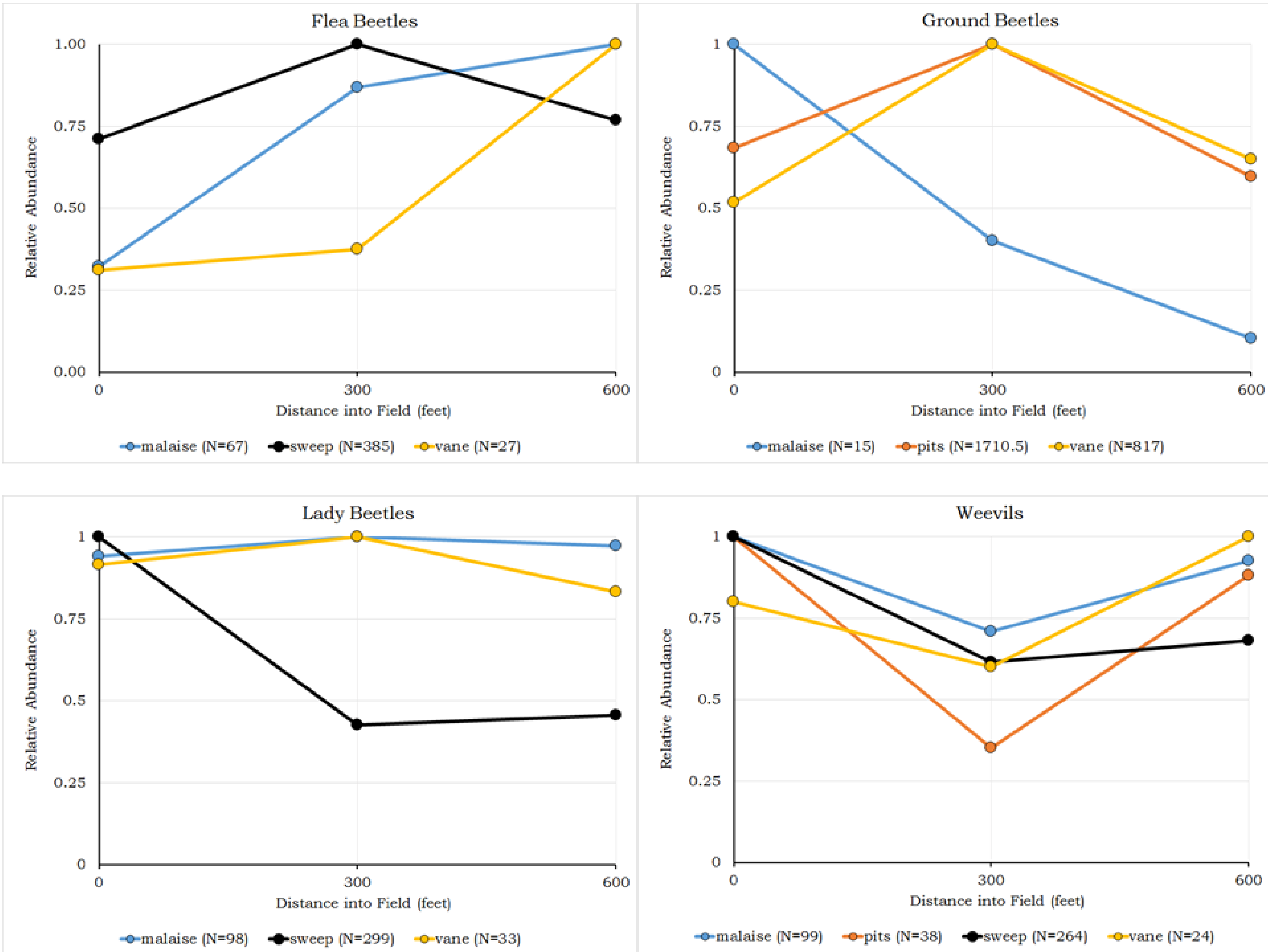
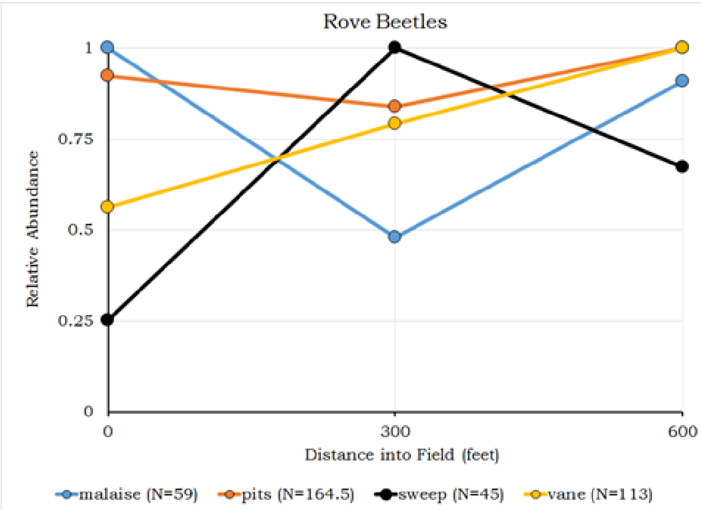
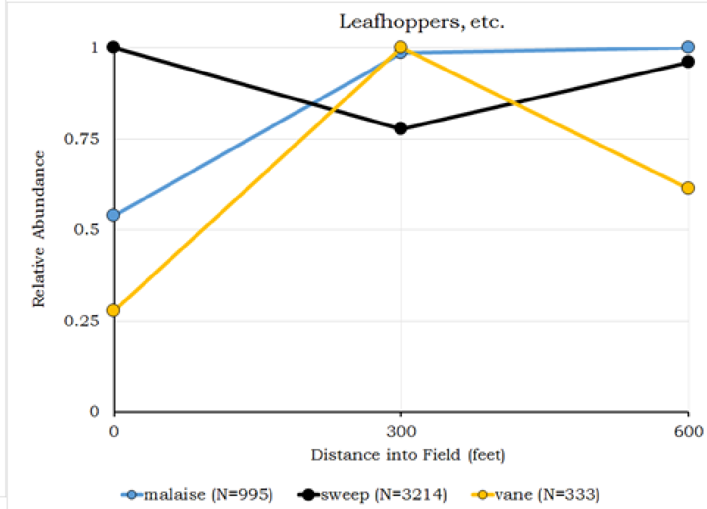


Fig. 1b. Relative abundance of flea beetles, ground beetles, lady beetles and weevils across three different distances and four different sampling techniques (few if any ground beetles were captured in sweep nets and few if any lady beetles were caught in pit traps).





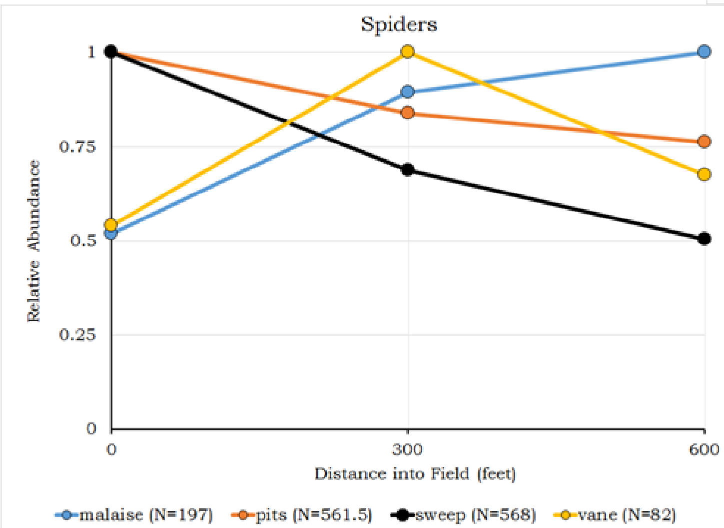


Fig. 1c.Relative abundances of rove beetles, leafhoppers and spiders across three different distances and four different sampling techniques (few if any leafhoppers were captured in vane traps).

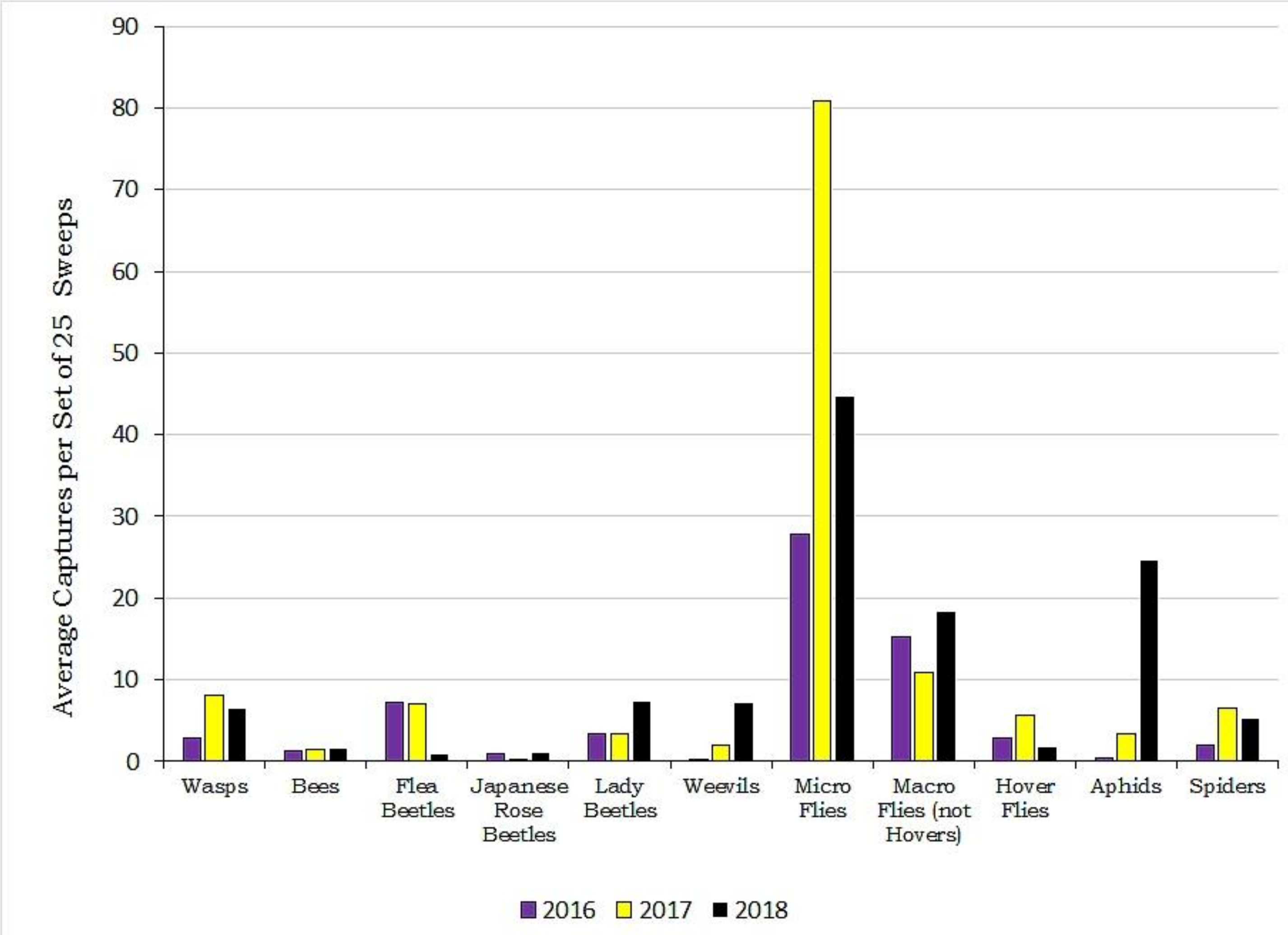


Fig. 2. Absolute captures of several groups in sweep net samples across the three years of monitoring. Note the apparently large inter-year variation in some groups.

Acknowledgements

Thanks to Dylan Cipkowski, Kendrick Fowler, Julia Meyer, Liam Henrie, Brenna Bushey, Rosa Villegas, and Claudia Knab-Vispo for help in the field and/or in the lab. Thanks to the Hudson Valley Farm Hub for their continued support and to Anne Bloomfield and other staff for facilitating our work.