Biodiversity Conservation on Agricultural Land:

The Vegetation and Flora of Petersham Country Club,

Harvard Forest, Petersham, MA

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November 2014

Acknowledgements

Thanks to David Foster and John Wisnewski for initiating this project and for providing much useful information and support. Thanks also to David Foster for use of photos included in this report. Special thanks to Martha Hoopes for field assistance and for substantial contributions to study design, permanent plot establishment, and vegetation sampling. Many thanks to Robert Bertin for kindly joining me on two field visits, reviewing specimens, guidance on species identification, and use of his data on the flora of Petersham. Thanks to Brian Hall for developing maps and figures, and gathering soil samples. The Harvard Forest Woods Crew provided helpful support. Roberta Lombardi and Karen Searcy provided assistance at the University of Massachusetts Herbarium. Thanks to Jenny Hobson, Taylor Orwig, Julie Pallant, and Dave Orwig for assistance at the Harvard Forest Herbarium.

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All other photos by David Foster.

Introduction

In the heavily-forested landscape of central New England, agricultural lands provide critical habitat for a wide range of early successional species, including numerous species of conservation concern. Working agricultural lands are likely to become increasingly important for biodiversity conservation in the coming decades, as residential and commercial development continue to expand across the region. In 2013, Harvard Forest (HF) acquired the property formerly owned by the Petersham Country Club (PCC), an approximately 70-acre property abutting the Prospect Hill Tract and the Bryant Farm. The PCC property was managed as a golf course from 1922 to 2012, with mowed grasslands that represent some of the largest open areas in an otherwise forested region. Acquisition of the former PCC and Bryant Farm properties presented a valuable opportunity for Harvard Forest to demonstrate approaches to biodiversity conservation in an agricultural setting that is characteristic of central New England.

Recognizing the biodiversity significance of agricultural land, Harvard Forest designated PCC as a demonstration site for biodiversity conservation within a working agricultural setting. In 2014, grazing of livestock and cutting of hay were initiated at the site, along with ongoing harvesting of woodlands to create brushy habitats for early successional species. The primary objective identified for PCC is to demonstrate the potential for biodiversity conservation on agricultural land rather than to establish a rigorous experimental framework for evaluating responses to agricultural management. Nonetheless, the introduction of agriculture to PCC presents interesting opportunities to evaluate ecological change over time. Because the site is likely to become increasingly interesting to ecologists and conservationists in the future, Harvard Forest initiated studies in 2014 to gather baseline data and to establish a plan for long-term vegetation monitoring. The current study was designed to gather information on the vascular flora of PCC prior to the introduction of agriculture, and to establish and sample a series of permanent plots that will be useful for evaluating change over time in response to agricultural management.

Specific objectives for 2014 included:

(1) Inventory the vascular flora of the former Petersham Country Club;

(2) Collect voucher specimens for the HF Herbarium of species that have not been documented previously from Harvard Forest, or that were found historically at HF but were not recorded in 2004–2007 by Jenkins et al. (2008);

(3) Establish and sample a series of permanent plots to characterize current vegetation composition, and to enable evaluation of vegetation change over time. It is anticipated that these permanent plots may also be used in the future to sample other taxa.

(4) Sample soils within permanent plots to document initial conditions and to facilitate future work on soil dynamics and ecosystem processes.

Management of PCC by Harvard Forest: 2013–2014

In order to create an extensive open landscape that provides habitats for a wide range of early successional species, Harvard Forest has initiated active management of the woodlands and fields at PCC. Harvesting of small wooded areas began in 2013 and is ongoing (Fig. 1). Harvested areas will be grazed and cut occasionally to maintain young, regenerating woodlands and other brushy habitats for early successional species.

Figure 1. Harvesting at PCC in 2013 created young regenerating woods and brushy habitats for early successional species.

Harvard Forest mowed the former golf course once in fall 2013. In 2014, the portion of the PCC property north of Poor Farm Rd. was designated for use as cow pasture. The northern section of the pasture will be managed as traditional pasture, and the southern section will be managed with intensive, rotational grazing (J. Wisnewski and D. Foster, pers. comm.). South of Poor Farm Rd., open areas will be used primarily for hay production, with some grazing after hay has been harvested. Grazing of the pasture began in mid-summer 2014, and the first cutting of hay occurred in late summer 2014 (Fig. 2).

Figure 2. Grazing of the pasture at PCC began in mid-summer 2014 (left); the first cutting of hay occurred in late summer 2014 (right).

Methods

Vascular Plant Inventory

In order to document the flora of PCC, field inventories were conducted from June through September 2014. Meander surveys were conducted in each of the major grassland areas (i.e., former fairways and putting greens) and each of the woodlands or brushy areas (Fig. 3), recording all vascular plant species that appeared to be naturally established. All areas were visited at least once, and most sections were visited both early and late in the growing season. Species that spread from plantings and appeared to be naturalized at the site were noted; no attempt was made to inventory numerous planted species that did not show clear evidence of having become naturalized at the site (e.g., *Echinacea purpurea*, *Hosta ventricosa*, etc.).

Voucher specimens were deposited at the Harvard Forest Herbarium of species that: (1) had not previously been reported from Harvard Forest, or (2) were reported historically but were not found in an inventory of Harvard Forest in 2004–2007 (Jenkins et al. 2008). Nomenclature and taxonomy follow Haines (2011). The word 'species' is used broadly in this report to refer to distinct taxa, including all identified species, subspecies, and varieties.

Permanent Plots

In order to document vegetation composition and abundance prior to agricultural grazing or mowing, a series of permanent plots was established across the former PCC lands. All plots were 10 m x 10 m and were subjectively located within areas of relatively uniform vegetation. A total of 27 plots were distributed as follows: 12 plots in grasslands on former fairways (four each in areas to be used for 'traditional grazing', 'intensive, rotational grazing', and 'hayfield'); nine plots on former putting greens (one on each green); and six plots in recently cut woodlands or brushy areas across the site (Fig. 3).

A compass and tape measure were used to lay out plots oriented to the cardinal directions, and corners were adjusted as needed by measuring the plot diagonals. All plot corners were permanently marked with 2-foot rebar with aluminum caps stamped to indicate the plot number and corner (i.e., 1-SW, 1-SE, etc.). Permanent markers were driven flush to the ground, and a painted 4' fiberglass rod was placed at the southwest corner of each plot to facilitate plot relocation. Minor (< 0.5 m) shifting of the location of permanent markers was occasionally needed to successfully drive rebar into rocky soils. Coordinates of the southwest corner of each plot were recorded using a Garmin 60 CSx GPS unit.

In each plot, all vascular plant species were recorded and the cover of each species estimated within the following classes: A=<1%; B=1–3%; C=4–5%; D=6–15%; E=16–25%; F=26–50%; G=51–75%; H=>75%). These classes were also used to estimate the cover of woody debris/leaf litter, rocks, and mineral soil within each plot. All plots were sampled prior to the initiation of grazing or mowing in mid-to-late summer 2014. However, because plots were sampled over a period of approximately two months, the ability to identify some taxa varied among plots. In particular, some taxa were identifiable to species only when reproductive

Figure 3. Aerial photo of the Petersham Country Club in 2005, with the location of 27 permanent plots established in summer 2014 (red squares). The boundary of the study area is shown in yellow; areas outside of this polygon that were formerly owned by PCC were not included in this study. Wooded portions of the study area were harvested by Harvard Forest in 2013–2014 to provide brushy habitat for early successional species.

material was present. As a result, grouping of taxa within the following genera is recommended for data analyses: *Agrostis, Digitaria, Epilobium, Hieracium, Plantago,* and *Taraxacum*. Estimates of the cover of grass species should also be used with caution because plots were sampled after the dominant grasses (especially *Agrostis* spp. and *Poa pratensis*) were 'matted down', making it difficult to accurately estimate cover.

In each plot, Brian Hall collected two mineral soil samples in summer 2014 (one each within one meter of the SW and NE corners). A cylindrical bulb planter (2.5" diameter) was used to collect surface mineral soils to a depth of 4.5" for analysis of soil texture, nutrients, and bulk density.

Results

Vascular Flora

The vascular flora of the former Petersham Country Club property is relatively diverse, with 367 species recorded in this survey (Appendix 1). Thirty-one species recorded at PCC were not previously documented from Harvard Forest and are considered 'new' species (Table 1). In addition, nine species found at PCC were reported historically from HF but were not relocated in 2004–2007 and were considered to be 'missing' from the modern HF flora by Jenkins et al. (2008; Table 2). Overall, 40 species recorded in this survey were not documented elsewhere at HF in 2004–2007, representing ~ 5% of the total extant flora reported by Jenkins et al. (2008). Five additional species (i.e., *Delphinium* sp., *Lychnis coronaria*, *Myosotis sylvatica*, *Veronica chamaedrys*, and an unidentified Poaceae species with variegated leaves) have spread locally from plantings at PCC but are not considered to be truly naturalized at this time.

Several additional species were reported from Harvard Forest between 2008 and 2013 (Appendix 2). Together with the results of this survey, approximately 45 species have been added to the flora of Harvard Forest as reported by Jenkins et al. (2008), bringing the total flora that has been observed at Harvard Forest (including PCC) since 2004 to over 770 species, and the total flora of Harvard Forest over the past century to over 840 species.

Approximately sixty percent of the taxa recorded at PCC are thought to be native, with the remaining 40% considered to be non-native. The percent of the flora at PCC that is non-native is substantially higher than elsewhere at Harvard Forest, where only 21% of the total flora (i.e., historical plus extant) was reported to be non-native (Jenkins et al. 2008). Of the 31 species recorded in this survey for which there were no prior Harvard Forest records, approximately three-quarters are non-native (Table 1).

Two species recorded in the current study are uncommon in the region (Cullina et al. 2011; Bertin and Rawinski 2012). A mustard species that is widespread at PCC has been tentatively identified as *Sisymbrium loeselii*, Loesel's mustard. This species has previously been recorded in Massachusetts only as a 'waif' rather than as an established member of the flora (Cullina et al. 2011). The last record of this species from Worcester County was collected in 1947 from wool waste in Barre, MA, where it is no longer extant and it is thought to have never

established (Bertin and Rawinski 2012). If specimens from PCC are confirmed to be *S. loeselii*, this may represent the first documented record of this species as part of the naturalized flora of Massachusetts. Collections of *Vulpia octoflora* var. *octoflora* from PCC also appear to be the first confirmed record of this variety from Massachusetts (Cullina et al. 2011).

Table 1. List of 'new' species found at PCC that have not been documented previously at Harvard Forest. Asterisks indicate species that have spread locally from plantings but do not yet appear to be fully naturalized. '+' indicates species that are thought to be native in New England, though some have spread from plantings at PCC (e.g., *A. saccharinum*). See Haines (2011) for comments on the status of *Vulpia octoflora*.

Acer platanoides	*Myosoton aquaticum*
Acer saccharinum+	*Nepeta cataria*
Amaranthus hybridus ssp. *hybridus*	Poaceae sp. – variegated*
Atocion armeria	*Raphanus raphanistrum*
Berteroa incana	*Salix cinerea*
Bromus commutatus	*Securigera varia*
Bromus inermis ssp. *inermis*	*Sisymbrium loeselii*
Cerastium arvense	*Sorbus aucuparia*
Cinna arundinacea+	*Symphyotrichum lanceolatum* ssp. *lanceolatum* var. *latifolium*+
*Delphinium sp.**	*Taraxacum laevigatum*
Euphorbia ×pseudo-esula	*Thlaspi arvense*
Eutrochium fistulosum+	*Trifolium hybridum*
Lactuca serriola	*Verbena urticifolia* var. *urticifolia*+
Lonicera ×bella	*Veronica chamaedrys**
Lotus corniculatus	*Viburnum lentago*+
*Lychnis coronaria**	*Viola ×bissellii*+
Mentha ×piperita	*Viola arvensis*
*Myosotis sylvatica**	*Vulpia octoflora* var. *octoflora*+

Table 2. List of species found at PCC that were reported from Harvard Forest historically but were not found in a 2004–2007 survey by Jenkins et al. (2008). A spiny *Ribes* species found at PCC in 2014 is included here as it likely to be either *R. hirtellum or R. cynosbati*; it could not be determined because of lack of reproductive material. *R. hirtellum* was collected at Harvard Forest in 1910. *R. cynosbati* was listed by J. G. Jack (1911) and reported from Petersham by H. M. Raup (1938), but specimens were not found to confirm that these records were from Harvard Forest. Neither species was found by Jenkins et al. (2008).

Alopecurus pratensis	*Potentilla canadensis*
Dianthus armeria	*Rhus glabra*
Erigeron pulchellus var. *pulchellus*	*Ribes* sp.
Fallopia convolvulus	*Viburnum opulus* ssp. *opulus*
Humulus lupulus ssp. *lupulus*	

Permanent Plots

A total of 168 species were recorded in 27 permanent plots. Species richness of plots in brushy areas was significantly higher than species richness of plots in former fairways or putting greens (Fig. 4; t-tests: $p < 0.01$). Plots in brushy areas (n=6) had an average species richness of ~ 54 species (range: 46–71), almost five times the species richness of plots on putting greens (avg.=11.56; range: 8–16; n=9) or fairways (avg.=11.08; range: 6–31; n=12). One plot out of 12 on fairways had substantially higher species richness (31 species) than the other fairway plots; excluding this outlier, remaining plots on fairways had an average species richness of 9.27 species (range: 6–14; n=11; Fig. 4).

High species richness in brushy areas apparently resulted from the occurrence, at moderate to low abundance, of numerous woodland species that persisted after harvesting together with many species that presumably established after harvesting (Fig. 5; Table 3). In contrast, most plots on fairways were characterized by a few dominant grass species (especially *Agrostis capillaris* and *Poa pratensis*), intermixed with other graminoids (e.g., *Festuca* spp., *Lolium perenne*, *Phleum pratense*) and occasional forbs (Fig. 6; Table 3).

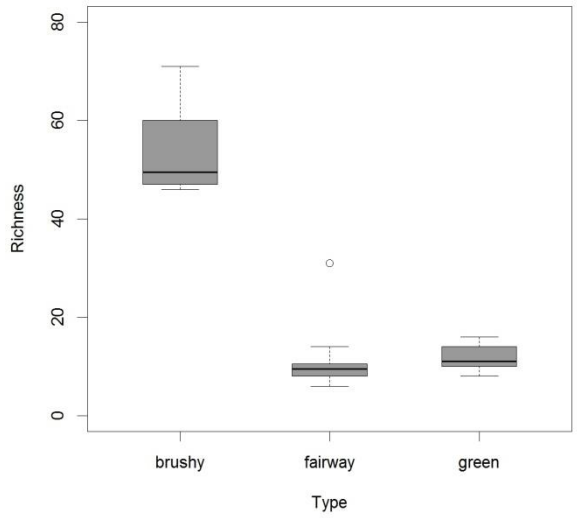

Figure 4. Box plot of species richness in plots sampled in brushy areas (n=6), fairways (n=12), and putting greens (n=9) at PCC. Median values are indicated by black lines within the grey bars (2nd and 3rd quartiles). 'Whiskers' extend to the maximum and minimum values, excluding outliers. Circle indicates an outlier fairway plot with 31 species.

In summer 2014, the putting greens were visually and compositionally distinct, being heavily dominated by dense patches of *Erigeron canadensis* up to 2 m tall (Fig. 6; Table 3). Prior to acquisition by HF, the putting greens were managed by the golf course for a uniform, dense cover of short grasses, especially *Agrostis capillaris*. Most of the grasses died on the greens in 2013–2014, presumably in response to lack of frequent watering after the closing of the country club. Death of the dominant grasses resulted in extensive areas of exposed 'duff' comprised of an approximately 1 cm deep layer of grass roots and other organic matter (Fig. 6). Across most of the putting greens, this layer of exposed duff was visible beneath dense stands of *Erigeron canadensis* in 2014. Upon drying, the exposed duff layer frequently developed irregular polygonal cracks, exposing sand or mineral soil beneath, and apparently facilitating colonization by forbs and grasses, especially *Trifolium repens*, *Digitaria* spp., *Plantago* spp., and *Taraxacum* spp. As additional species become established, it is likely that the putting greens may become less visually and compositionally distinct over time.

Table 3. Frequency (%) and mean cover ($\bar{x}$) of species in different plot types at PCC. Species recorded in fewer than three plots are omitted. Mean cover is based on the cover class mid-point for plots in which a species occurred.

	Plot Type					
	Brushy (n=6)		Fairway (n=12)		Green (n=9)	
Species	**%**	**$\bar{x}$**	**%**	**$\bar{x}$**	**%**	**$\bar{x}$**
Rubus allegheniensis	100	17				
Solidago rugosa	100	6	8	1	22	1
Rubus idaeus	100	4				
Rhus hirta	100	1				
Oxalis stricta	100	1			11	1
Lonicera morrowii	83	19			11	1
Impatiens capensis	83	9				
Celastrus orbiculatus	83	7	17	1		
Populus tremuloides	83	3				
Parthenocissus quinquefolia	83	2				
Euthamia graminifolia	83	1	8	1	11	1
Solidago gigantea	83	1				
Carex spp.	83	1				
Vitis labrusca	83	1				
Erechtites hieraciifolius	83	1	8	1		
Potentilla simplex	83	1	17	3		
Fraxinus americana	83	1				
Galeopsis bifida	83	1				
Lactuca biennis	83	1				
Persicaria maculosa	83	1				
Fragaria virginiana	83	1	8	5		
Carex scoparia	67	4	17	1		
Acer rubrum	67	2	8	1	11	1
Solidago altissima	67	2			22	1
Prunus serotina	67	1	42	1	11	1
Juncus effusus s. l.	67	1				
Oenothera biennis	67	1				
Symphyotrichum lateriflorum	67	1			11	1
Arisaema triphyllum	67	1				
Carex debilis	67	1				
Eurybia divaricata	67	1				
Quercus rubra	67	1	8	1		
Phellodendron amurense	50	7				
Toxicodendron radicans	50	7				
Rosa multiflora	50	4	8	1		
Lysimachia quadrifolia	50	2				
Athyrium angustum	50	1				
Dichanthelium clandestinum	50	1				
Onoclea sensibilis	50	1				
Osmunda claytoniana	50	1				
Berberis thunbergii	50	1				
Carex radiata	50	1				
Doellingeria umbellata	50	1				
Dryopteris intermedia	50	1				
Lobelia inflata	50	1				
Maianthemum canadense	50	1				
Phytolacca americana	50	1				
Prunus virginiana	50	1				
Rubus hispidus	50	1				

Cirsium vulgare	50	1			22	1
Dactylis glomerata	33	1			11	1
Juncus tenuis	33	1	17	1		
Epilobium sp.	33	1	8	1		
Agrostis sp.	67	2	100	57	89	19
Poa pratensis	33	1	100	27		
Lolium perenne	17	1	67	2	22	1
Phleum pratense	17	1	50	2		
Festuca trachyphylla	50	1	25	11		
Trifolium repens	17	1	58	6	89	4
Digitaria sp.	33	1	50	1	89	8
Cerastium fontanum	17	1	25	1	44	1
Erigeron canadensis	67	1	67	2	100	40
Taraxacum spp.			75	1	100	1
Plantago spp.			50	1	100	1
Erigeron annuus	17	1	8	1	78	1
Cerastium arvense			17	1	11	1
Chenopodium album					33	1
Polygonum aviculare			8	1	22	1

Figure 5. High species richness in brushy areas apparently results from the persistence of woodland species after harvesting (note sprouting in top photo) in combination with the establishment of new species in harvested areas (bottom). The tall flowering species in the bottom photo is *Eutrochium fistulosum*, a species recorded in this survey that has not previously been reported from Harvard Forest.

Figure 6. Former fairways (top) and putting greens (bottom) at PCC. In 2014, most plots on fairways were dominated by *Agrostis capillaris* and/or *Poa pratensis*. Estimates of the cover of individual grass species were difficult because grasses were 'matted down' (upper right) when sampling occurred in mid- to late-summer. Grasses (e.g., *A. capillaris*) that formerly dominated most putting greens died in 2013 or 2014, leaving extensive areas of exposed 'duff' (light gray areas in lower left photo). In 2014, putting greens supported dense stands of tall *Erigeron canadensis* (bottom right, bright green) above the exposed 'duff' layer.

Discussion

Several regional assessments have highlighted the importance of grasslands, shrublands, and other early successional habitats for a wide range of species of conservation concern (e.g., Barbour et al. 1998; MA DFW 2005; Woolsey et al. 2010; MAS 2011). In heavily-forested regions such as central New England, agricultural lands provide critical habitats for many early successional species, including numerous rare or uncommon species. Results of this study confirm that PCC supports a high diversity of vascular plant species, including numerous species that are uncommon or absent from nearby woodlands.

Several native plant species were documented in this study that have not previously been reported from Harvard Forest, in addition to several species that occurred historically but were not re-located in a 2004–2007 survey of Harvard Forest by Jenkins et al. (2008). Based on the declining rate at which new species were found at PCC late in the study period, it is likely that 90% or more of the extant vascular flora was documented in the current inventory. Jenkins et al. (2008) reported 729 species at Harvard Forest from 2004–2007, and accepted records of a total of 808 species from HF over the previous century. Although PCC is < 3% as large as the ~ 3,000-acre area surveyed by Jenkins et al. (2008), the 367 vascular plant species recorded in this survey represent ~ 50% of the number of species found at HF from 2004 to 2007 (Jenkins et al.

2008). This pattern of species richness is generally consistent with species-area relationships noted throughout the region (Jenkins et al. 2008).

Jenkins et al. (2008) reported the historical flora of Harvard Forest (i.e., documented prior to 2000) as 637 species, of which 79 species (12%) were not relocated in their 2004–2007 survey. Approximately 32 of these 'missing' species were recorded at PCC (9 species) or elsewhere in Petersham (23 species; R. Bertin unpubl. data) since 2000. Thus, fewer than 50 species that were documented historically at Harvard Forest have not been re-located in Petersham since 2000. Targeted searches are needed to determine whether any of these species persist locally, and to identify those species that have apparently been lost from the local flora.

From 2000 through 2010, Robert Bertin conducted extensive field work throughout Petersham as part of a project to document the flora of Worcester County (Bertin and Rawinski 2012). In addition to many species known from Harvard Forest, he recorded more than 100 species in Petersham that were not found at Harvard Forest by Jenkins et al. (2008) or earlier HF surveys, and were not found in the current study of PCC (R. I. Bertin, unpublished data). Bertin also recorded more than 20 species in Petersham that were found historically at Harvard Forest but were not re-located there by Jenkins et al. (2008). Adding R. Bertin's records to those of Jenkins et al. (2008) and those of the current survey of PCC, approximately 900 species have been reported from the Town of Petersham since 2000. Based on these sources as well as earlier specimens collected at Harvard Forest and elsewhere in Petersham (i.e., HF herbarium; R.I. Bertin, unpublished data), more than 1000 species have been recorded in Petersham since the early 20th century. Petersham thus has a larger documented current flora and a larger documented historical flora than all other towns or cities in Worcester County with the exception of the City of Worcester (Bertin, 2000, 2002; R. Bertin, pers. comm.). The large documented flora for Petersham compared to other towns in the county undoubtedly results in part from the history of detailed floristic studies at Harvard Forest over the past century.

Management Considerations

Harvard Forest has designated PCC as a model site for demonstrating approaches to biodiversity conservation on working agricultural lands. In order for agricultural land to provide long-term biodiversity benefits, it is critical that agriculture remain economically viable. At the same time, management of agricultural land in a manner that promotes biodiversity conservation may require some modification of conventional agricultural practices. For instance, in order to maintain productive populations of uncommon grassland bird species, harvesting of hay should be delayed until after the grassland bird nesting season (MAS 1997). However, postponing the cutting of hay until after the breeding season necessarily involves some reduction in hay production and income for farmers, potentially limiting their ability or willingness to delay cutting. One approach to address this concern is to increase the value of hay that is cut in late summer. At PCC, this could be accomplished by no-till seeding of late-season grasses such as big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), or other species that would improve the quality and value of hay harvested after the grassland bird breeding season (J. Wisnewski, pers. comm.). Importantly, this approach would both increase the abundance of native grass species at PCC and provide a meaningful model for addressing some of the economic concerns associated with biodiversity conservation on farmlands across the region.

Although no rare plant species were documented at PCC in 2014, field observations confirm that PCC already provides habitat for some openland bird species of regional conservation concern. For instance, several bobolinks were observed through the nesting season in 2014, including one pair that demonstrated food-carrying and territorial behavior that indicated probable nesting (G. Motzkin, pers. obs.). American woodcocks also nested at PCC in 2014 (D. Foster, pers. comm.), in a brushy area in the pasture created by harvesting a small woodland. Although comprehensive bird surveys were not conducted in 2014, several additional bird species of regional conservation interest were observed during field work for this survey, including American Kestrel, Cooper's Hawk, Eastern Bluebird, Indigo Bunting, Least Flycatcher, and Great Blue Heron. Focused surveys of grassland birds and other taxa are recommended for 2015 to document extant biodiversity at PCC and to enable evaluation of changes that may occur in the future in response to agricultural practices.

Recommended Future Studies

In order to document current biodiversity at PCC and to evaluate changes over time in response to the introduction of agriculture, several additional studies are recommended:

- Invasive plant species (e.g., *Lonicera morrowii, Rosa multiflora, Berberis thunbergii*, etc.) are currently widespread across PCC, with dense populations in some areas of brushy vegetation. Baseline maps and data on the distribution and abundance of invasive species should be gathered to document current conditions and to evaluate changes in the abundance and distribution of these species over time.

- Permanent plots established in 2014 should be re-sampled periodically. Initial re-sampling at intervals of ~ 5-years may be warranted to document changes associated with the introduction of agriculture at PCC.

- Occasional field visits should be conducted throughout the growing season in the next few years to note any additions to the vascular flora of PCC. A comprehensive re-survey of the vascular flora in 5–10 years is recommended to document changes in the flora associated with the introduction of agriculture.

- Baseline data on taxa other than plants (e.g., birds, Lepidoptera), including complete species lists and estimates of abundance, should be gathered as soon as possible to document initial conditions at PCC and to facilitate evaluation of change over time. In addition, it is recommended that Harvard Forest organize one or more 'bio-blitz' efforts in 2015 in which local and regional experts in various taxonomic groups gather over 1–2 days to generate comprehensive species lists for a wide range of taxa. This represents a low-cost and efficient way to gather good baseline information for numerous taxonomic groups that are likely to be of interest in the future (e.g., bees, beetles, odonates, etc.). Specimens of any invertebrates collected as part of such an effort should be deposited at HF or MCZ.

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Appendix 1. List of vascular plant species recorded at PCC in 2014.

Acalypha rhomboidea
Acer platanoides
Acer rubrum
Acer saccharinum
Acer saccharum var. *saccharum*
Achillea millefolium ssp. *lanulosa*
Actaea pachypoda
Aegopodium podagraria
Ageratina altissima var. *altissima*
Agrimonia gryposepala
Agrostis capillaris
Agrostis gigantea
Agrostis scabra
Alliaria petiolata
Alopecurus pratensis
Amaranthus hybridus ssp. *hybridus*
Ambrosia artemisiifolia
Amelanchier laevis
Andropogon gerardii
Antennaria sp.
Anthoxanthum odoratum
Apios americana
Apocynum androsaemifolium
Aquilegia canadensis
Aralia elata
Aralia nudicaulis
Aralia racemosa ssp. *racemosa*
Arctium minus
Arisaema triphyllum var. *triphyllum*
Aronia sp.
Arrhenatherum elatius
Artemisia vulgaris var. *vulgaris*
Asclepias exaltata
Asclepias syriaca
Athyrium angustum
Atocion armeria
Barbarea vulgaris
Berberis thunbergii
Berteroa incana
Betula alleghaniensis
Betula lenta
Betula papyrifera
Betula populifolia
Bidens frondosa
Brachyelytrum aristosum
Bromus commutatus
Bromus inermis ssp. *inermis*
Bulbostylis capillaris
Calamagrostis canadensis
Callitriche heterophylla var. *heterophylla*
Capsella bursa-pastoris
Carex annectens
Carex appalachica
Carex arctata
Carex crinita var. *crinita*
Carex debilis var. *rudgei*
Carex gynandra
Carex Laxiflorae sp.
Carex lupulina
Carex lurida
Carex normalis
Carex pallescens
Carex pensylvanica
Carex projecta
Carex radiata
Carex scoparia var. *scoparia*
Carex stipata var. *stipata*
Carex swanii
Carex vesicaria
Carex virescens
Carex vulpinoidea
Castanea dentata
Celastrus orbiculatus
Cerastium arvense
Cerastium fontanum ssp. *vulgare*
Chelidonium majus
Chenopodium album
Cinna arundinacea
Circaea canadensis ssp. *canadensis*
Cirsium vulgare
Comptonia peregrina
Convallaria majalis
Coptis trifolia
Corylus cornuta ssp. *cornuta*
Crataegus sp.
Cuscuta gronovii
Cyperus strigosus
Cypripedium acaule
Dactylis glomerata
Danthonia compressa
Danthonia spicata
Daucus carota
Delphinium sp.
Dennstaedtia punctilobula
Dianthus armeria
Dianthus barbatus
Dianthus deltoides
Dichanthelium acuminatum ssp. *fasciculatum*
Dichanthelium clandestinum
Diervilla lonicera
Digitaria ischaemum
Digitaria sanguinalis
Doellingeria umbellata var. *umbellata*
Dryopteris carthusiana
Dryopteris intermedia
Dryopteris marginalis
Echinochloa crus-galli
Elaeagnus umbellata var. *parvifolia*

Eleocharis elliptica
Elymus repens
Epilobium ciliatum
Epipactis helleborine
Equisetum arvense
Eragrostis pilosa var. *pilosa*
Erechtites hieraciifolius var. *hieraciifolius*
Erigeron annuus
Erigeron canadensis
Erigeron pulchellus var. *pulchellus*
Erigeron strigosus
Erysimum cheiranthoides
Euonymus alatus
Eupatorium perfoliatum
Euphorbia ×pseudo-esula
Eurybia divaricata
Euthamia graminifolia
Eutrochium dubium
Eutrochium fistulosum
Fallopia convolvulus
Fallopia cilinodis
Fallopia japonica var. *japonica*
Fallopia scandens
Festuca filiformis
Festuca rubra
Festuca trachyphylla
Fragaria virginiana ssp. *virginiana*
Frangula alnus
Fraxinus americana
Galeopsis bifida
Galium mollugo
Galium palustre
Galium triflorum
Geranium maculatum
Glechoma hederacea
Glyceria canadensis
Glyceria striata
Gnaphalium uliginosum
Hemerocallis fulva
Hieracium aurantiacum
Hieracium caespitosum
Hieracium pilosella
Hieracium piloselloides
Houstonia caerulea
Humulus lupulus ssp. *lupulus*
Hylotelephium telephium
Hypericum canadense
Hypericum perforatum ssp. *perforatum*
Hypericum punctatum
Ilex verticillata
Impatiens capensis
Ionactis linariifolia
Iris versicolor
Juncus effusus ssp. *solutus*
Juncus pylaei
Juncus tenuis
Juniperus communis var. *depressa*
Lactuca biennis
Lactuca canadensis
Lactuca serriola
Leersia oryzoides
Leonurus cardiaca
Lepidium virginicum var. *virginicum*
Leucanthemum vulgare
Linaria vulgaris
Lindera benzoin
Lobelia inflata
Lolium perenne
Lonicera ×bella
Lonicera morrowii
Lotus corniculatus
Luzula multiflora ssp. *multiflora*
Lychnis coronaria
Lycopus uniflorus
Lyonia ligustrina var. *ligustrina*
Lysimachia borealis
Lysimachia nummularia
Lysimachia quadrifolia
Lysimachia terrestris
Lythrum salicaria
Maianthemum canadense
Maianthemum racemosum ssp. *racemosum*
Malus sieboldii
Matricaria discoidea
Medicago lupulina
Medicago sativa
Melilotus alba
Mentha x piperita
Mimulus ringens
Mitchella repens
Mollugo verticillata
Muhlenbergia frondosa
Myosotis sylvatica
Myosoton aquaticum
Nabalus trifoliolatus
Nepeta cataria
Nuphar variegata
Nuttallanthus canadensis
Oclemena acuminata
Oenothera biennis
Onoclea sensibilis
Osmunda claytoniana
Osmundastrum cinnamomeum
Oxalis dillenii
Oxalis stricta
Pachysandra terminalis
Panicum capillare ssp. *capillare*
Parathelypteris noveboracensis
Parthenocissus quinquefolia
Persicaria hydropiper
Persicaria longiseta
Persicaria maculosa

Persicaria pensylvanica
Persicaria sagittata
Phalaris arundinacea
Phellodendron amurense
Phleum pratense
Phlox paniculata
Phragmites australis ssp. *australis*
Phytolacca americana var. *americana*
Pilea pumila var. *pumila*
Pinus strobus
Plantago lanceolata
Plantago major
Plantago rugelii
Poa annua
Poa nemoralis
Poa palustris
Poa pratensis ssp. *pratensis*
Poaceae sp. (variegated)
Polygonatum pubescens
Polygonum aviculare
Polystichum acrostichoides
Populus grandidentata
Populus tremuloides
Potamogeton berchtoldii
Potentilla argentea
Potentilla canadensis
Potentilla norvegica
Potentilla recta
Potentilla simplex
Prunella vulgaris ssp. *lanceolata*
Prunus pensylvanica var. *pensylvanica*
Prunus serotina var. *serotina*
Prunus virginiana var. *virginiana*
Pteridium aquilinum ssp. *latiusculum*
Pyrola elliptica
Quercus alba
Quercus rubra
Quercus velutina
Ranunculus abortivus
Ranunculus acris
Ranunculus bulbosus
Raphanus raphanistrum
Rhamnus cathartica
Rhus glabra
Rhus hirta
Ribes rubrum
Ribes sp.
Robinia pseudoacacia
Rosa multiflora
Rubus allegheniensis
Rubus flagellaris
Rubus hispidus
Rubus idaeus ssp. *strigosus*
Rudbeckia hirta var. *pulcherrima*
Rumex acetosella ssp. *pyrenaicus*
Rumex crispus ssp. *crispus*
Rumex obtusifolius ssp. *obtusifolius*
Sagina procumbens
Salix cinerea
Salix discolor
Salix sericea
Sambucus nigra ssp. *canadensis*
Saponaria officinalis
Schedonorus arundinaceus
Schizachyrium scoparium var. *scoparium*
Scirpus atrocinctus
Scirpus cyperinus
Scirpus hattorianus
Scirpus microcarpus
Scleranthus annuus
Scorzoneroides autumnalis ssp. *autumnalis*
Scutellaria lateriflora
Securigera varia
Setaria faberi
Setaria pumila ssp. *pumila*
Silene latifolia ssp. *alba*
Sisymbrium loeselii
Sisymbrium officinale
Sisyrinchium montanum var. *crebrum*
Smilax herbacea
Solanum dulcamara
Solanum ptycanthum
Solidago altissima ssp. *altissima*
Solidago arguta var. *arguta*
Solidago bicolor
Solidago canadensis
Solidago gigantea
Solidago juncea
Solidago puberula var. *puberula*
Solidago rugosa ssp. *rugosa*
Sonchus asper
Sorbus aucuparia
Sparganium americanum
Spergularia rubra
Spiraea alba var. *latifolia*
Spiraea tomentosa
Stellaria graminea
Swida alternifolia
Swida rugosa
Symphyotrichum cordifolium
Symphyotrichum laeve var. *laeve*
Symphyotrichum lanceolatum ssp. *lanceolatum* var. *latifolium*
Symphyotrichum lateriflorum
Symphyotrichum novi-belgii
Symphyotrichum puniceum var. *puniceum*
Symphyotrichum racemosum
Taraxacum laevigatum
Taraxacum officinale
Thelypteris palustris var. *pubescens*
Thlaspi arvense
Toxicodendron radicans ssp. *radicans*

Trifolium arvense
Trifolium aureum
Trifolium campestre
Trifolium hybridum
Trifolium pratense
Trifolium repens
Tsuga canadensis
Turritis glabra
Typha latifolia
Ulmus americana
Urtica dioica ssp. *gracilis*
Uvularia sessilifolia
Vaccinium angustifolium
Vaccinium corymbosum
Vaccinium fuscatum
Verbascum thapsus
Verbena hastata var. *hastata*
Verbena urticifolia var. *urticifolia*
Veronica arvensis
Veronica chamaedrys
Veronica officinalis
Veronica serpyllifolia ssp. *serpyllifolia*
Viburnum acerifolium
Viburnum dentatum var. *lucidum*
Viburnum lantanoides
Viburnum lentago
Viburnum nudum var. *cassinoides*
Viburnum opulus ssp. *opulus*
Vicia cracca ssp. *cracca*
Viola ×bissellii
Viola arvensis
Viola sagittata var. *ovata*
Vitis labrusca
Vitis riparia
Vulpia octoflora var. *octoflora*
Zizia aurea

Appendix 2. Recent observations on the flora of Harvard Forest.

The following observations on the flora of Harvard Forest, recorded after the 2004–2007 survey by Jenkins et al. (2008), may be useful to those involved with future efforts to document the flora of Harvard Forest:

- A population of *Platanthera grandiflora* found in the Simes Tract in 2008 by A. Barker-Plotkin (HF Herbarium: GM and ABP specimen HF003039) was undoubtedly present but overlooked in the 2004–2007 survey by Jenkins et al. (2008).

- *Tussilago farfara* was found in 2013 on the Prospect Hill Tract in the Locust Opening clearcut of a former red pine plantation (HF Herbarium: GM and EF specimens HF003031, 003032, 003033). Jenkins et al. (2008) searched for this species but did not find it at HF in 2004–2007. It is unlikely that this species occurred in the Locust Opening red pine plantation prior to the harvest in 2008.

- *Carex tonsa* var. *rugosperma* was collected in 2013 on the Prospect Hill Tract in the Fisher Pines clearcut (HF Herbarium: GM specimens HF003034, 003035). G. Motzkin also recorded field observations of this species in 2013 in the Locust Opening clearcut, and in the Harvard Pond clearcut in the Tom Swamp Tract. Jenkins et al. (2008) noted that the vegetative plants they recorded as *Carex umbellata* from Tom Swamp Tract in 2004–2007 may have been the closely related *C. tonsa*.

- Robert Bertin recorded a field observation of *Dryopteris campyloptera* in September 2008 from moist conifer woods near the Natural History Trail on the Prospect Hill Tract, southeast of Shaler Hall. R. Bertin and G. Motzkin were unable to re-locate this species at the site in 2012.

- *Vitis riparia* was reported with some uncertainty by Jenkins et al. (2008) from the Simes Tract, based on specimens that R. Bertin considered to be *V. aestivalis* (i.e., GM specimens HF 2006-6; 2006-7). *Vitis riparia* was confirmed at PCC in 2014 (HF Herbarium: GM specimen HF003551).

- *Osmorhiza claytonii* was recorded in the Simes Tract during the 2004–2007 survey (HF Herbarium: GM specimen HF 2005-663) but was accidentally omitted from the report and summary tallies of Jenkins et al. (2008).

- Numerous mounted and unmounted specimens collected from Harvard Forest or Petersham will soon be transferred from Bentley University to Harvard Forest. These specimens have not yet been reviewed to identify possible additions to the Harvard Forest flora, and to gather information on species distributions within Harvard Forest. A spreadsheet of specimens from the Bentley University collection lists three species (i.e., *Claytonia caroliniana*, *Luzula acuminata*, and *Viola renifolia*) for which there are no other historical or current records from Harvard Forest. If these specimens are correctly identified, they represent additions to the historical flora of Harvard Forest.