FLORAL AND FAUNAL RESEARCH ON UTILITY RIGHTS-OF-WAY AT STATE GAME LANDS 33 AND GREEN LANE RESEARCH AND DEMONSTRATION AREAS

2015-2018

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https://sites.psu.edu/transmissionlineecology/

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Cover Photographs include images of integrated vegetation management along the right-of-way at State Game Lands 33, identification and preparation of pollinators at Penn State's Frost Entomological Museum, and examples of target floral and faunal taxa researched during the project. Photographs were taken by project members during the summers of 2016 and 2017.

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INTRODUCTION

Integrated vegetation management on rights-of way

Electrical right-of-way (ROW) vegetation management methods arrest plant growth and, therefore, provide early successional habitat that is compatible with electrical powerlines and favored by many floral and faunal species (Komonen et al. 2012, Wagner et al. 2014). One way to achieve this compatible vegetation cover is through Integrated Vegetation Management (IVM). IVM utilizes a variety of management approaches to achieve a desired vegetation community type. These approaches may include chemical, manual, and mechanical techniques (e.g., Johnstone 2008). The response of vegetation to IVM is important because vegetation communities can change within a relatively short time due to natural plant succession. In general, the 2 phases of IVM along electrical ROW are: 1) use of a herbicidal spray or mechanical treatment to initially control the density of target (non-compatible) trees, i.e., those that have the potential of growing to a height that is not compatible with safe ROW maintenance, such as maples, cherrys, or oaks, and 2) development of a tree-resistant plant cover type to reduce target tree invasion of the ROW. On electrical ROW, the wire zone - border zone method (Figure I-1) is recommended to provide diverse wildlife habitat (Yahner 2004), with low-lying vegetation in the wire zone and taller vegetation in the border zone to create habitat diversity.

Numerous studies have demonstrated that a taxonomically diverse array of early successional species is favored by IVM under electric transmission lines, including numerous grasses, sedges, forbs, pollinators (bees, butterflies, moths, beetles, flies), reptiles, grassland and shrubland birds, mammals, and others (Bramble et al. 1997, Litvaitis et al. 1999, Yahner et al. 2004, 2007, Komonen et al. 2013, Wagner et al. 2014). In the northeastern U.S. and elsewhere, where early successional habitats are decreasing (Litvaitis et al. 1999, DeGraaf and Yamasaki 2003), ROW can provide critical habitat for numerous species of conservation concern that rely on this habitat type (DeGraaf and Yamasaki 2003).

Wildlife response and current research

This research is a continuation of a project that began in 1953 when researchers at The Pennsylvania State University designed an initial study to test the effects of herbicides and other vegetation management approaches on natural resources including plant communities and various wildlife groups (e.g., Bramble and Byrnes 1979) in electrical ROW. The project was initiated on State Game Lands (SGL) 33 in Centre County, Pennsylvania with several partners including Pennsylvania Electric Company (now First Energy Corp.), the Pennsylvania Game Commission, DuPont, AmChem (now Dow AgroSciences) and Asplundh Tree Expert Co. Similar studies have been conducted at a companion site, Green Lane Research and Demonstration Area (GLR&D), in Montgomery County, Pennsylvania since 1987. The year

2018 marked the 65th year of the original study - making SGL33 the site of the longest continuous study measuring the effects of herbicides and mechanical vegetation management practices on plant diversity, wildlife habitat, and wildlife use within a ROW. This report represents the findings from research conducted from 2015-2018 on the effects of ROW vegetation maintenance on vegetation, bird, and bee communities (a separate bee report additionally was provided in 2017; https://sites.psu.edu/transmissionlineecology).

Legacy vegetation treatments

For 65 years, multiple methods of vegetation management were evaluated side by side to determine the effects on floral and faunal communities on a ROW at SGL 33 and GLR&D. Manual (and later, mechanical) brush cutting was compared to the use of herbicides in their effectiveness at controlling vegetation. Different types of herbicides and various means of application were also evaluated. Initially, at SGL 33, six mechanical and herbicidal treatment sites (with replicates) were established (Table I-1; legacy treatments). These legacy treatments included: hand-cutting (HC), mowing (M), mowing plus herbicide (MH), foliage spray (F), stem foliar spray (SF), and basal low volume (BLV) (to be precise, basal high volume was used before BLV) (Table I-1). At the GLR&D site, five legacy treatments (no BLV) each with two replicates were established in 1987. In addition, the treatments were managed to include a 50-foot (16 m) border zone on each side with a 75 foot (23 m) wire zone (Figure I-1). Each treatment replicate unit was approximately 3 acres (1.2 ha) in size at SGL 33 and 2.5 acres (1 ha) in size at GLR&D.

Current vegetation treatment terminology and approaches

Over the years, IVM terminology has changed and current treatment names and approaches reflect this evolution in vegetation management (Table I-1). Current terminology and approaches are as follows: mowing cut stubble (MCS) instead of MH, low volume basal (LVB) instead of BLV, high volume foliar (HVF) instead of F, and ultra-low volume foliar (ULVF) instead of SF. Mowing and hand-cutting remain consistent in terminology and approach (see Appendix A for further descriptions, sample photos, and treatment schedule).

Despite these general treatment approaches, actual vegetation treatments are adaptive and based on integrated vegetation management (IVM). Therefore, treatment labels and terminology may not reflect *actual* recent treatment applied---creating some confusion. In general, sites are visited and “reset” once every 4-6 years based on IVM prescriptions with mechanical and chemical treatments applied in order to maintain an early successional stage of vegetation within the ROW. Thus, treatments were not necessarily applied consistently at each 4-6 year vegetation maintenance period (Table I-1). For example, at SGL 33, legacy site ‘F1’ which, in current terminology, is a high-volume foliar treatment (HVF), was *actually* maintained in 2016 using the ULVF treatment (Table I-1). These changes have resulted in only one treatment at SGL 33 that has been consistently treated with mowing (M4), for example. Furthermore, over the years, certain treatment units have been rotated out of use. There is no longer a MCS treatment 2, for example at SGL 33. Hand-cut (HC) treatments, however, have remained consistent at both SGL 33 and GLR&D as have low volume basal treatments (at least recently). Treatments were applied at GLR&D in 2014 (versus 2016 at SGL 33) and have remained consistent over the years (Appendix A).

Land managers also visit the ROW annually and apply treatment as needed in response to annual plant growth, with the priority of ensuring that the vegetation does not interfere with the electrical transmission lines. At these annual visits, herbicide is applied only where it is needed on non-compatible plant species (e.g., potential canopy tree species that have the ability to grow to a height that could interfere with electric lines). In order to comply with new federal safety regulations (ferc.gov) on utility ROW, the recent management at SGL 33 and GLR&D included removal of 10 ft (3 m) of transitional border zone on each side of the wire zone. This removal, increased the width of the wire zone and, necessarily reduced the border zone width. Due to these recent developments, we present the vegetation and bird community results in the context of the current treatments, rather than the legacy treatments. Please note that in the bee portion of this report, legacy treatment names are still used. This usage is an artifact of study design and database development.

Outreach

The data that was, and is, generated from the ROW project continues to be vital and practical in understanding the implications of IVM on ROW maintenance and on floral and faunal communities. Additionally, SGL 33 is regularly toured by vegetation management professionals, conservationists, sportsmen, foresters, policy makers, and students as it exemplifies one of the best, if not the best, representation of long-term study of electrical powerline management techniques. Over the past 3 years, we have shared numerous public outreach, academic, and industry presentations and articles (Appendix B) - continuing a long tradition of disseminating the findings from these important research and demonstration projects (Figure I-2).

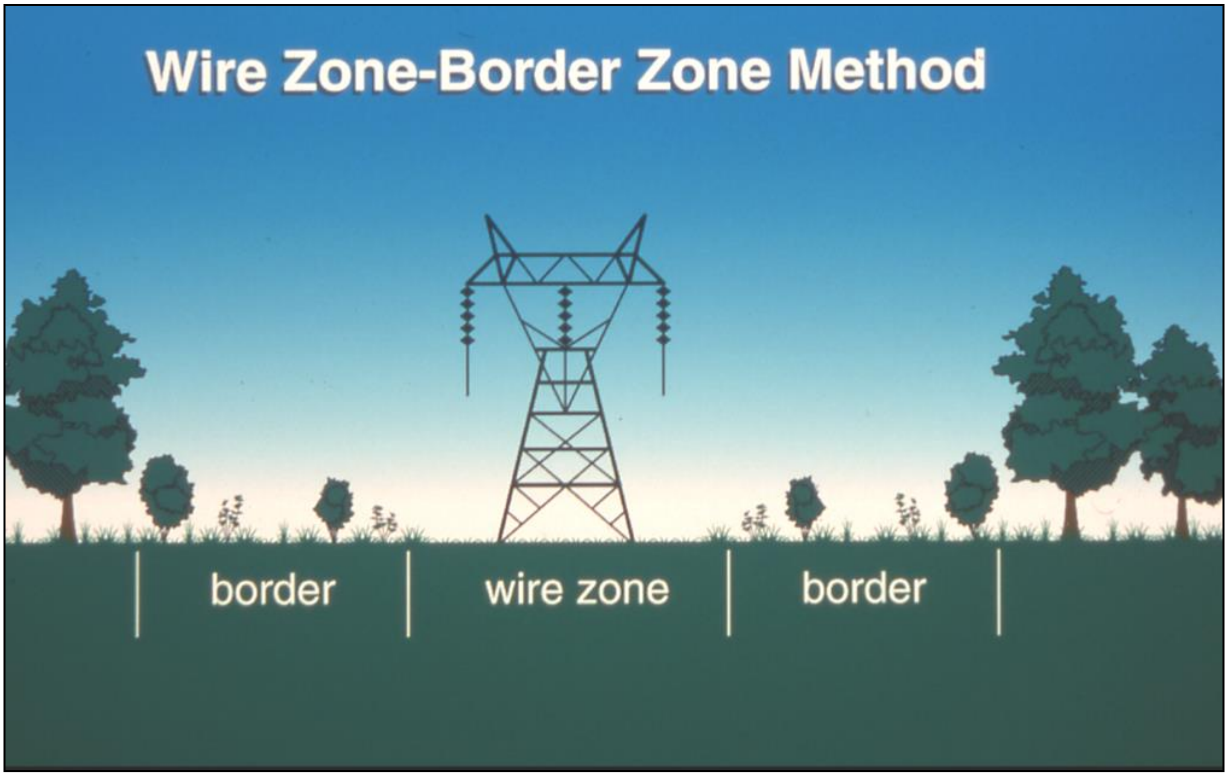

Figure I-1. Wire Zone - Border Zone method of integrated vegetation management at State Game Lands 33 and Green Lane Research and Demonstration Area. The border zone is approximately 50 feet wide (16 m) on either side of the right-of-way with a 75 foot (23 m) wire zone.

Table I-1. History of vegetation acronyms, treatments, terminology, and most recent vegetation treatment applied at State Game Lands 33. For more information and Green Lane Research and Demonstration Area information, see Appendix A.

Legacy acronym	Legacy treatment	Current terminology (acronym)	2016 treatment applied
HC1	Hand Cut Unit 1	Hand Cut (HC)	Hand Cut
BLV3	Basal Low Volume Unit 3	Low Volume Basal (LVB)	Low Volume Basal
MH1	Mow Herbicide Unit 1	Mow Cut Stubble (MCS)	Ultra Low Volume Foliar
BLV1	Basal Low Volume Unit 1	Low Volume Basal (LVB)	Low Volume Basal
F1	Foliage Spray Unit 1	High Volume Foliar (HVF)	Ultra Low Volume Foliar
M1	Mowing Unit 1	Mowing (M)	Ultra Low Volume Foliar
BLV4	Basal Low Volume Unit 4	Low Volume Basal (LVB)	Low Volume Basal
HC2	Hand Cut Unit 2	Hand Cut (HC)	Hand Cut
SF1	Stem Foliar Unit 1	Ultra Low Volume Foliar (ULVF)	Ultra Low Volume Foliar
M2	Mowing Unit 2	Mowing (M)	Ultra Low Volume Foliar
BLV2	Basal Low Volume Unit 2	Low Volume Basal (LVB)	Low Volume Basal
MH3	Mow with Herbicide Unit 3	Mow Cut Stubble (MCS)	Ultra Low Volume Foliar
SF2	Stem Foliar Unit 2	Ultra Low Volume Foliar (ULVF)	High Volume Foliar
F2	Foliage Spray Unit 2	High Volume Foliar (HVF)	High Volume Foliar
M4	Mowing Unit 4	Mowing (M)	Mowing
C1	Integrated Vegetation Management	Integrated Vegetation Management (IVM), no borders	Ultra Low Volume Foliar, no borders
C2	Integrated Vegetation Management	Integrated Vegetation Management (IVM), no borders	Ultra Low Volume Foliar, no borders

Figure I-2. Project cooperators and researchers visit the right-of-way research and demonstration site at State Game Lands 33 in June 2017. Photo: Hannah Stout, Penn State.

VEGETATION

Methods

Vegetation was measured on the SGL 33 and GLR&D sites in July 2016. We sampled vegetation in late July to correspond to maximum plant emergence at our study sites - realizing the plants with short growing and/or blooming seasons (e.g., spring ephemerals) may be missed. Our sampling also occurred prior to the reduction in border-zone width (due to federal energy regulatory commission regulations [ferc.gov]) that occurred in August 2016. We used sampling techniques developed for the research project (see Bramble et al. 1991) that, in turn, had been modified from vegetation sampling techniques developed by Braun and Blanquet (see Moore 1962). This vegetation sampling approach is transect-based and species are identified and documented as follows: non-compatible trees at least 1 foot (0.3 m) in height were recorded within 2-3 permanent transect belts (each 66 feet [20.1 m] long x 6.6 feet [2 m] wide) in wire zones and within 2-4 corresponding permanent transect belts (each 33 feet [10.1 m] long x 6.6 feet [2 m] wide) that extended east and west within adjacent border zones of each unit. Only trees rooted in transect belts were counted, i.e., trees rooted outside the belt with foliage extending into the belt were not counted. We then calculated the total number of non-compatible trees/acre in each treatment unit and zone (a typical transect in a wire zone, was equivalent to 0.10 acre). We noted the maximum height (to the nearest foot) of non-compatible trees in both wire and border zones of each unit in the vicinity of each transect belt. Plant cover types were determined within a 16.5-feet (5 m) radius plot placed in the center of each transect belt in wire and border zones, using the Braun-Blanquet method for estimating abundance and sociability of major plants. From these estimates within each treatment unit, we calculated plant cover type(s) in each unit as forb, grass or shrub. In addition, plant species and relative abundance were noted with each center plot. Where possible, we compared our data to unpublished reports (see Yahner 2012, for example) or past published studies of plant species richness from our study sites (e.g., Yahner and Hutnik 2005, Yahner et al. 2008).

We used the United Kindgom's Natural History Museum global database of larval host plants to identify potential Lepidopteran species present on the SGL 33 ROW (http://www.nhm.ac.uk/our-science/data/hostplants/). Host plants present on the ROW were documented in our vegetation sampling and past published studies of plant species richness at SGL 33 (Yahner and Hutnik 2005). In addition, some larval host species were documented anecdotally during other wildlife studies. Once potential Lepidopteran larval host plants were documented, we used published field guides (e.g., Monroe and Wright 2017) and distribution maps and databases (e.g., https://www.inaturalist.org/projects/butterflies-and-moths-of-pennsylvania) to assemble a final list of potential species.

Results

Target tree (non-compatible species) invasion and cover type

State Game Lands 33

Invasion by individuals of non-compatible tree species on the ROW increased from 2012 to 2017 in the wire (40%) and border zones (56%) when all units were considered together (Table V-1). Wire zone units with the lowest density of non-compatible trees were ULVF (average = 200 trees/acre) and HVF (average = 100 trees/acre) treatments. The only treatment with no recorded non-compatible trees was the wire zone of LVB unit #3 (Table V-1). Mechanical treatments (M, HC) had the highest density of non-compatible tree species with an average of 567 trees/acre and 3050 trees/acre, respectively, in the wire zones. In general, these findings reflect those of earlier studies that indicate that integrated vegetation management is effective at limiting the invasion of non-compatible overstory tree species in ROW compared to mechanical treatments (Yahner and Hutnik 2005, Yahner et al. 2008). As expected, border zones, contained higher density of non-compatible tree species compared with the wire zone. As explained earlier in this report, border zones are managed to permit greater shrub and tree growth (wildlife habitat diversity) and, therefore, higher densities of woody vegetation are permitted in these areas. In addition, because border zones are located adjacent to mature forest, there is a greater likelihood for non-compatible tree species to naturally colonize and persist in this zone (Yahner 2012a).

Due to management objectives, border zones across the study area were dominated by the shrub cover type. In addition, HC units were dominated by shrubs in the wire zone. All other treatments and units varied in the dominant cover type in the wire zone. In general, however, half of the wire zone units (regardless of treatment) were dominated by forb cover in 2016. Grass was only dominant in one MCS and one LVB treatment (Table V-1). Dominant cover type also varied from 2012 data with forbs replacing shrubs in some LVB treatments and shrubs replacing forbs in the only consistently mowed unit (M #4) (Table V-1).

Green Lane Research and Demonstration Area

Invasion by individuals of non-compatible tree species on the ROW decreased from 2012 to 2016 in the wire (16 %) zone but increased in the border zones (182%) when all units were considered together (Table V-2). All wire zone treatments have essentially the same density of non-compatible tree species with 300-350 trees/acre in each treatment. Therefore, we could not differentiate the effect of ROW treatment (mechanical, herbicide) on non-compatible tree invasion within the wire zone at GLR&D. We believe one reason for this lack of differentiation among treatments is due to the complicating effects of the immediately-adjacent ROW which is managed by Pennsylvania Power and Light (PPL) electric utilities according to separate ROW maintenance guidelines and schedule. As such, our vegetation treatment replicates are not isolated and, we believe, vegetation response is affected by the vegetation treatment and management on the immediately-adjacent ROW.

As expected, border zones contained higher density of non-compatible tree species compared to the wire zone (890 trees/acre versus 320 trees/acre across all treatments; TableV-2). Border zones are managed to permit greater shrub and tree growth and, therefore, higher densities of woody vegetation persist in these units.

Across all treatments and units, grass was the dominant cover type in M wire zone units while forbs persisted as the dominant cover type in all other wire zone units. This finding is consistent with other research that indicates mowing promotes grasses while other treatments—including selective herbicide application is more conducive to forb growth (Yahner et al. 2008).

Maximum tree height

<u>State Game Lands 33</u>

As in past studies, maximum non-compatible tree heights varied among zones and treatment units. As expected, maximum height in border zones was higher (16.2 feet) than in wire zones (7.2 feet) (Table V-3). Among wire zone treatments, non-compatible trees were taller in HC (15 feet) and LVB (9.3 feet) treatments, on average, than in other treatment units. However, as noted in the previous section, the only wire zone treatment with no non-compatible trees present was the LVB unit #3 (Table V-3). The most commonly encountered tallest non-compatible tree species were oaks (red [*Quercus rubra*], white [*Q. alba*], chestnut [*Q. montana*]) in both the wire and border zones.

<u>Green Lane Research and Demonstration Area</u>

As in past studies, maximum non-compatible tree height varied among zones and treatment units. As expected, maximum height in borders zones was higher (17.7 feet) than in wire zones (5.1 feet) (Table V-4). Among wire zone treatments, non-compatible trees were shortest in MCS treatments, while all other treatments contained non-compatible trees that were essentially equal in height (Table V-4). The most commonly encountered tallest non-compatible tree species regardless of treatment or unit was white ash (*Fraxinus americana*, 30%) followed by red cedar (*Juniperus virginiana*). Red cedar was not documented as a tallest tree in any treatment in 2012 and natural successional processes have led to its emergence at GLR&D over the past 5 years (Yahner 2012b). In addition, it is interesting to note that white ash is persisting at GLR&D despite the spread of Emerald Ash Borer which has been present in PA since 2007 (dcnr.pa.gov).

Compatible plant species richness

Plant species richness recorded at all treatment and units was much lower than that recorded in earlier summaries published for the ROW research (e.g., Yahner et al. 2008). These differences are due to the following:

1. We conducted vegetation species richness quantitatively (plot- and transect- based) at one point during the growing season (maximum plant emergence) in late July. Previous work conducted by Bramble and Byrnes focused on collecting plant species richness data qualitatively throughout the growing season (May-August) (see Yahner et al. 2008).

2. We kept non-compatible tree data separate from shrub, forb, and herbaceous plant data. Therefore, our species richness summaries reflect compatible vegetation (e.g., excludes overstory tree species) present on all treatment and units at our ROW study sites.

Despite these differences, we still present earlier data (most recently published species richness data available) for comparative purposes. In particular, percentage of native versus non-native plants present in each treatment unit and relative species richness data is informative from a ROW ecology perspective.

<u>State Game Lands 33</u>

In July 2016, we encountered an average of 12 species of plants in wire zone treatments at SGL 33 with 73.9% of these species being native (Table V-5). In 2006, by contrast, 88.9% of plant species encountered in the wire zone on all treatments were native species. Within the wire zone, HC and LVB treatments had the highest species richness (18 and 14.7 species, respectively) in 2016. In 2005, within the wire zone, the ULVF and MCS had the highest plant species richness on average. However, in 2005, LVB has the single highest plant species unit (regardless of wire or border zone) with 50 plant species recorded in LVB #3. In 2005, within the wire zone, M treatment units had the lowest species richness on average. In 2016, M treatment units in the wire zone also had the lowest plant species richness, on average, even though ULVF management was used in the 2016 ROW maintenance at all but one of these treatment units (Table V-5).

Non-native plant species

State Game Lands 33

With regards to non-native species, MCS and ULVF treatments had the highest percentage of non-native species in both 2005 and 2017. Interestingly, LVB, HC, and M had the highest, native plant species richness in both 2005 and 2017 (~ 93%; Table V-5). Regardless of year, however, these results indicate that integrated vegetation management is compatible with maintaining plant species richness in ROW.

Green Lane Research and Demonstration Area

In July 2016, we encountered an average of 21 species of compatible plant species in wire zone treatments at GLR&D with 67% of these species being native (Table V-6). In 2006, 70% of plants encountered in the wire zone at GLR&D were native species. Within the wire zones, M treatments had the highest overall species richness but 33% of these species were non-native. The highest native species richness was found in the MCS treatments where only 22% of the species were non-native; however, total species richness in MCS was the lowest of all our treatments in 2016. Therefore, it was difficult for us to detect a clear trend or effect of treatment on plant species richness at the GLR&D study sites. Again, we believe this is due to the confounding effects of the PPL electric utility ROW located immediately adjacent to our treatments that is managed in a manner separate and inconsistent with our study.

Lepidopteran larval host plants

We found that 225 species of Lepidopteran larva (butterflies and moths) potentially could be present on the ROW at SGL 33 (Appendix C). Again, these numbers reflect potential species present due to the availability of larval host plant species on the ROW. Bramble et al. (1997) documented 32 species of adult butterfly (they did not count moths) using flowers as food sources at SGL 33. Further research is necessary to determine how many of the potential species listed are actually present in our treatment units at SGL 33. In addition, we note that many species of trees that are non-compatible for ROW are used by larval Leptidoptera (e.g., many species of oak). Therefore, the surrounding landscape of mature deciduous forest may provide the seed source and seedlings that are used by many Lepidoptera species on this ROW in central Pennsylvania.

Discussion

Integrated vegetation management requires basic and applied knowledge coupled with appropriate effort and treatment approaches that include mechanical and chemical approaches (Nowack and Ballard 2005). The overall goal of IVM is to achieve specific management objectives that, in the case of ROW, result in early successional, stable vegetation communities. As noted, chemical application is part of the IVM 'tool box' and our research indicates proper use of herbicides is compatible with supporting native plant communities that, in turn, support a variety of wildlife species.

Selective use of herbicides could assist with the removal of non-native vegetation from the landscape. The increase in non-native plants is especially evident on SGL 33 where there proportion of the plant community has increased over the past decade. For example, when post-emergent herbicide was applied to research plots with the goal of removing non-native Japanese stiltgrass (*Microstegium vimineum*) in Indiana, forb richness was greater than in untreated plots and was equivalent to hand-weeding and much more efficient (Flory and Clary 2009).

The message of the compatibility of proper herbicide use and wildlife habitat management should not be understated as more areas limit or prevent the use of herbicides in vegetation management. For example, in Quebec, chemical herbicides have been banned on Crown forest lands since 2001 (Thiffault and Roy 2011). This ban has created numerous challenges in terms of increased cost and reduced forest regeneration/productivity despite the fact that herbicides, when used in a targeted and appropriate context, have not been shown to reduce the species richness, diversity, or abundance of vertebrate wildlife in forest ecosystems - especially when compared to agricultural systems (see Sullivan and Sullivan 2002 for a review related to glyphosate; Miller and Miller 2004). Furthermore, Sullivan and Sullivan (2002) note that changes in mean species richness and diversity of vascular plants from the effects of herbicide treatment in forestry were within mean values of natural fluctuations. However, they do note that herbicide treatment may result in shift in species composition - a stated and desired goal of IVM (Nowack and Ballard 2005).

Table V-1. Number of non-compatible trees/acre (> 1 foot tall) in wire zones and border zones of 17 treatment units and 7 treatments on the State Game Lands 33 Rights-of-Way Research and Demonstration Area in 2016 (for comparison, data from 2012 are in parentheses). Dominant cover type (forb, grass, or shrub) for wire zone is also presented. Borders were all dominated by shrubs.

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2016)	Wire Zone	Border Zone	Dominant cover type - wire zone
Mowing/Mowing	1 (ULVF)	600 (700)	1300 (800)	Shrub (Shrub)
	2 (ULVF)	1100 (600)	800 (500)	Forb (Shrub)
	4 (M)	0 (900)	1700 (1500)	Shrub (Forb)
	Average	**566.7 (733.3)**	**1266.7 (933.3)**	
Mowing plus herbicide/ Mowing cut stubble	1 (ULVF)	200 (0)	1300 (300)	Grass (Grass)
	3 (ULVF)	300 (0)	700 (400)	Forb (Grass)
	Average	**250 (0)**	**1000 (350)**	
Stem foliar/ Ultra low volume foliar	1 (ULVF)	200 (0)	1000 (800)	Forb (Grass)
	2 (HVF)	200 (100)	1200 (300)	Grass (Forb)
	Average	**200 (50)**	**1100 (550)**	
Foliage spray/ High volume foliar	1 (ULVF)	100 (300)	1200 (200)	Forb (Shrub)
	2 (HVF)	100 (0)	1000 (400)	Forb (Forb)
	Average	**100 (150)**	**1100 (300)**	
Basal low volume/ Low volume basal	1 (LVB)	200 (400)	1400 (600)	Shrub (Shrub)
	2 (LVB)	300 (300)	800 (700)	Shrub (Shrub)
	3 (LVB)	0 (300)	700 (300)	Forb (Shrub)
	4 (LVB)	700 (700)	1800 (2100)	Forb (Shrub)
	Average	**333.3 (433.3)**	**1100 (1033.3)**	
Hand cut/Hand cut	1 (HC)	4700 (2000)	8200 (5300)	Shrub (Shrub)
	2 (HC)	1400 (1600)	5100 (4000)	Shrub (Shrub)
	Average	**3050 (1800)**	**6650 (4650)**	
Control no border	1 (IVM)	400		Shrub (na)
	2 (IVM)	1000		Forb (na)
	Average	**700**		
All treatments		742.8 (527.8)	2035.1 (1302.8)	

Table V-2. Number of non-compatible trees/acre (> 1 foot tall) in wire zones and border zones of 10 treatment units and 5 treatments on the Green Lane Rights-of-Way Research and Demonstration Area in 2016. Dominant cover type (forb, grass, or shrub) for wire zone is also presented (for comparison, data from 2012 are in parentheses). Borders were all dominated by shrubs.

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2014)	Wire Zone	Border Zone	Dominant cover type - wire zone
Mowing/Mowing	1 (M)	200 (0)	1400 (300)	Forb (Grass)
	2 (M)	500 (0)	200 (500)	Grass (Grass)
	Average	**350 (0)**	**800 (400)**	
Mowing plus herbicide/ Mowing cut stubble	1 (MCS)	400 (100)	300 (400)	Grass (Grass)
	2 (MCS)	200 (0)	300 (300)	Grass (Grass)
	Average	**300 (50)**	**300 (350)**	
Stem foliar/ Ultra low volume foliar	1 (ULVF)	400 (200)	400 (500)	Forb (Forb)
	2 (ULVF)	300 (200)	300 (400)	Forb (Grass)
	Average	**350 (200)**	**350 (450)**	
Foliage spray/ High volume foliar	1 (HVF)	200 (1100)	1400 (50)	Forb (Grass)
	2 (HVF)	400 (0)	1200 (100)	Forb (Grass)
	Average	**300 (550)**	**1300 (75)**	
Hand cut/Hand cut	1 (HC)	100 (500)	100 (200)	Forb (Shrub)
	2 (HC)	500 (1700)	3300 (400)	Forb (Forb)
	Average	**300 (1100)**	**1700 (300)**	
All treatments		320	890	

Table V-3. Height (ft) of tallest tree species in wire zones and border zones of 17 treatment units and 7 treatments on the State Game Lands 33 Rights-of-Way Research and Demonstration Area in 2016 (for comparison, height [ft] of tallest tree from 2012 are in parentheses).

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2016)	Wire Zone	Border Zone
Mowing/Mowing	1 (ULVF)	12 Chestnut Oak (6)	22 Black Cherry (20)
	2 (ULVF)	12 Chestnut Oak (6)	25 Red Maple (25)
	4 (M)	0 (6)	12 White Oak (25)
	Average height	**8 (6)**	**19.7 (23.3)**
Mowing plus herbicide/ Mowing cut stubble	1 (ULVF)	1 Red Oak (3)	17 Sassafras (35)
	3 (ULVF)	2 Red Maple (10)	25 Red Oak (30)
	Average height	**1.5 (6.5)**	**21 (32.5)**
Stem foliar/ Ultra low volume foliar	1 (ULVF)	3 White Oak (10)	15 Red Maple (25)
	2 (HVF)	5 Black Cherry (20)	20 Red Maple (20)
	Average height	**4 (15)**	**17.5 (22.5)**
Foliage spray/ High volume foliar	1 (ULVF)	6 White Oak (6)	15 Red Oak (30)
	2 (HVF)	6 Black Cherry (20)	7 Red Oak (20)
	Average height	**6 (13)**	**11 (25)**
Basal low volume/ Low volume basal	1 (LVB)	7 Red Maple (8)	15 White Oak (20)
	2 (LVB)	15 White Oak (12)	15 Red Maple (30)
	3 (LVB)	0 (10)	6 Hawthorn (25)
	4 (LVB)	15 Red Oak (20)	15 Red Oak (20)
	Average height	**9.3 (12.5)**	**12.8 (23.8)**
Hand cut/Hand cut	1 (HC)	15 Black Cherry (15)	15 Chestnut Oak (17)
	2 (HC)	15 Black Cherry (8)	15 Black Cherry (18)
	Average height	**15 (11.5)**	**15 (17.5)**
Control (no border)	1 (IVM)	10 Black Cherry	na
	2 (IVM)	3 Hawthorn	na
	Average height	**6.5**	
All treatments		7.2 (9.2)	16.2 (24.1)

Table V-4. Height (ft) of tallest tree species in wire zones and border zones of 10 treatment units and 5 treatments on the Green Lane Research and Demonstration Area in 2016 (for comparison, height [ft] of tallest tree from 2012 are in parentheses).

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2014)	Wire Zone	Border Zone
Mowing/Mowing	1 (M)	6 Flowering Dogwood (0)	20 Hophornbeam (30)
	2 (M)	4 Pignut Hickory (0)	20 White Ash (30)
	Average height	**5 (0)**	**20 (30)**
Mowing + herbicide/ Mowing cut stubble	1 (MCS)	3 White Ash (6)	15 Red Maple (25)
	2 (MCS)	2 White Ash (0)	7 White Ash (15)
	Average height	**2.5 (3)**	**11 (20)**
Stem foliar/Ultra low volume foliar	1 (ULVF)	5 Red Cedar (30)	15 Red Cedar (20)
	2 (ULVF)	5 Red Cedar (14)	5 Flowering Dogwood (14)
	Average height	**5 (22)**	**10 (17)**
Foliage spray/ High volume foliar	1 (HVF)	6 Flowering Dogwood (8)	25 Flowering Dogwood (10)
	2 (HVF)	8 Red Cedar (25)	20 White Ash (22)
	Average height	**7 (16)**	**22.5 (16)**
Hand cut/Hand cut	1 (HC)	4 Sassafras (5)	35 Red Cedar (20)
	2 (HC)	8 White Ash (7)	15 Red Maple (9)
	Average height	**6 (6)**	**25 (14.5)**
All treatments		5.1	17.7

Table V-5. Total number of compatible plant species and native plant species in wire and border zones of 17 treatment units and 7 treatments on the State Game Lands 33 Rights-of-Way Research and Demonstration Area in July 2016 (for comparison, data from May-August 2005 are in parentheses).

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2016)	Wire Zone	Wire Zone Native; percentage	East Border Zone	West Border Zone	Average Border Zone Native; percentage
Mowing/Mowing	1 (ULVF)	10 (22)	7 (21); 70% (95%)	15	10	10.5 (31); 83% (97%)
	2 (ULVF)	11 (39)	9 (36); 82% (92%)	12	6	7.5 (34); 83% (97%)
	4 (M)	13 (30)	10 (28); 77% (93%)	12	11	9.5 (32); 82% (94%)
	Average	**11.3 (30.3)**	**8.7 (28.3); 76.3% (93.3%)**	**13**	**13.5**	**9.2 (32.3); 82.7% (96%)**
Mowing + herbicide/ Mowing cut stubble	1 (ULVF)	11 (34)	8 (28); 73% (82%)	13	8	10.5 (37); 81% (97%)
	3 (ULVF)	13 (43)	8 (33); 62% (76%)	20	13	11.5 (36); 68% (88%)
	Average	**12 (38.5)**	**8 (30.5); 67.5% (79%)**	**16.5**	**10.5**	**11 (36.5); 74.5% (92.5%)**
Stem foliar/Ultra low volume foliar	1 (ULVF)	9 (34)	6 (31); 67% (91%)	13	12	10 (38); 79% (97%)
	2 (HVF)	9 (47)	5 (37); 56% (79%)	13	na	11 (33); 85% (80%)
	Average	**9 (40.5)**	**5.5 (34); 61.5% (85%)**	**13**	**12**	**10.5 (35.5); 82% (88.5%)**
Foliage spray/ High volume foliar	1 (ULVF)	9 (29)	7 (28); 78% (96%)	12	8	8 (31); 79% (97%)
	2 (HVF)	10 (36)	7 (31); 70% (86%)	13	na	11 (34); 85% (92%)
	Average	**9.5 (32.5)**	**7 (29.5); 74% (91%)**	**12.5**	**8**	**9.5 (32.5); 82% (94.5%)**

Table V-5. (continued).

Legacy Treatment/ New Treatment Term	Replicate Unit (Current Treatment 2016)	Wire Zone	Wire Zone Native; percentage	East Border Zone	West Border Zone	Average Border Zone Native; percentage
Basal low volume/ Low volume basal	1 (LVB)	10 (23)	7 (22); 70% (96%)	13	13	10.5 (32); 81% (100%)
	2 (LVB)	10 (32)	8 (31); 80% (97%)	11	11	8.5 (39); 77% (95%)
	3 (LVB)	19 (50)	13 (40); 68% (80%)	22	13	15.5 (34); 83% (74%)
	4 (LVB)	15 (31)	13 (31); 87% (100%)	11	13	10.5 (31); 88% (100%)
	Average	**14.7 (37.7)**	**11.3 (34); 78.3% (92.3%)**	**14.7**	**12.3**	**11.5 (34.7); 82.7% (89.7%)**
Hand cut/Hand cut	1 (HC)	11 (27)	10 (27); 91% (100%)	12	14	11 (38); 85% (93%)
	2 (HC)	25 (42)	20 (36); 80% (86%)	na	18	14 (38); 78% (93%)
	Average	**18 (34.5)**	**15 (31.5); 85.5% (93%)**	**12**	**16**	**12.5 (38); 81.5% (93%)**
Control (no border)	1 (IVM)	10	7; 70%	na	na	na
	2 (IVM)	9	7; 78%	na	na	na
	Average	**9.5**	**7; 74%**			
All treatments		12 (35.7)	8.9 (31.3); 73.9% (88.9%)	13.6	12.1	10.7 (34.9); 80.9% (92.4%)

Table V-6. Total number of compatible plant species and native plant species in wire and border zones of 10 treatment units and 5 treatments the Green Lane Rights-of-Way Research and Demonstration Area in 2016 (for comparison, data from May-August 2005 are in parentheses).

Legacy Treatment/ New Treatment Terminology	Replicate Unit (Current Treatment 2014)	Wire Zone	Wire Zone Native; percentage	North Border Zone	South Border Zone	Average Border Zone Native; percentage
Mowing/Mowing	1 (M)	26 (52)	17; 65% (34, 65%)	14	14	8.5; 61% (25, 71%)
	2 (M)	19 (35)	13; 68% (25, 71%)	12	17	8; 56% (19, 73%)
	Average	**35.5 (44)**	**23.5; 66.5% (30, 68%)**	**13**	**15.5**	**8.25; 58.5% (22, 71%)**
Mowing plus herbicide/ Mowing cut stubble	1 (MCS)	20 (33)	16; 80% (19, 58%)	12	13	8; 64% (30, 83%)
	2 (MCS)	12 (34)	9; 75% (24, 71%)	11	9	7.5; 74% (19, 68%)
	Average	**16 (34)**	**12.5; 77.5% (22, 65%)**	**11.5**	**11**	**7.75; 69% (24, 75%)**
Stem foliar/Ultra low volume foliar	1 (ULVF)	18 (39)	11; 61% (29, 74%)	10	13	8; 70% (24, 80%)
	2 (ULVF)	15 (60)	11; 73% (40, 67%)	14	14	9.5; 68% (25, 74%)
	Average	**16.5 (50)**	**11; 67% (35, 70%)**	**12**	**13.5**	**8.5; 69% (24, 75%)**
Foliage spray/High volume foliar	1 (HVF)	20 (48)	14; 70% (33, 69%)	12	9	6.5; 63% (33, 77%)
	2 (HVF)	21 (34)	13; 62% (31, 75%)	14	13	7.5; 55% (23, 82%)
	Average	**20.5 (41)**	**13.5; 66% (31, 75%)**	**13**	**11**	**7; 59% (28, 78%)**
Hand cut/Hand cut	1 (HC)	20 (36)	9; 45% (24, 67%)	14	na	8; 57% (17, 71%)
	2 (HC)	16 (43)	11; 69% (34, 79%)	8	15	8.5; 74% (24, 86%)
	Average	**18 (40)**	**10; 57% (29, 73%)**	**11**	**15**	**8.3; 65.5% (20, 77%)**
All treatments		21.3	14.1; 66.8%	12.1	13.2	8; 64.2%

BREEDING BIRDS

Methods

We implemented fixed-width transect singing surveys to determine levels of breeding bird activity on Rights-of-Way (ROW) at State Game Lands 33 (SGL 33) and Green Lane Research and Demonstration Areas (GLR&D) (Keller et al. 2009). Four surveys were conducted per year during the breeding season between 20May and 7July for three consecutive years (2015-17). Birds within 50m of the ROW were identified and recorded based on where they were initially detected (i.e., wire zone, border zone, imediately-adjacent Pennsylvania Power and Light electric utilities (PPL) ROW [at GLR&D], or forest adjacent to the ROW [at SGL 33]). Study sites at GLR&D contained a border zone only on the east side of the ROW before transitioning to mature forest while the west side of the wire zone was adjacent to and paralleled the PPL ROW before abutting mature forest. Study sites at SGL 33 contained border zones on each side of the ROW before transitioning to mature forest. On GLR&D, we designed our surveys to encompass two replicates of each of the five management treatments (legacy treatments) within the wire zone including hand cutting, mowing, mowing with herbicide application, low volume stem and foliar herbicide application, and high volume foliar herbicide application (Appendix A). For SGL 33, we designed our study to incorporate two replicates of each of the original six management treatments within the wire zone (legacy treatments) including hand cutting, mowing, mowing with herbicide application, low volume stem and foliar herbicide application, high volume foliar herbicide application, and low volume basal herbicide application (Table I-1). To examine the possible importance of border zones to breeding bird activity, during 2016 and 2017 at SGL 33, we added two replicates of low volume foliar herbicide application treatments that contained a 125 foot wire zone and no border.

In order to further evaluate breeding bird activity at SGL 33, during 2016 and 2017 we conducted surveys to assess avian productivity following Pennsylvania Breeding Bird Atlas guidelines (Laughlin et al. 1990, Wilson et al. 2012). At least 3, one-hour time periods spaced throughout the breeding season were spent by observers (minimum of six person hours) at each site per year to detect and monitor breeding bird activity and determine the breeding status (possible, probable, confirmed) of each avian species (Laughlin et al. 1990, Yahner et al. 2004, Yahner et al 2005, Wilson et al. 2012). Additionally, researchers followed the chronology of active nests through completion of nesting activity (e.g., when the nest was determined to have been abandoned by the parents, preyed upon, or until the young successfully fledged). Each active nest was checked at 2-4 day intervals depending on weather conditions and projected time of nestling fledging (Yahner and Ross 1995, Ross 2001). Nesting attempts were deemed successful if any young survived and fledged the nest.

To determine whether the management treatments or the difference between years had an effect on bird abundance and species richness or indices of breeding bird productivity, we used general linear mixed effects models (GLMMs) and general linear models (GLM) with Poisson distribution aggregated by time (Bates et al. 2014). We used these models because they are able to handle the uneven sampling introduced by the current treatments (as compared to the legacy treatments) and because they can partition variation in the data to fixed and random effects. We used survey year as a random effect and the different surveys as replicates for each site. The fixed effect was management treatment. We also used GLMMs to determine whether survey year had a significant effect on the abundance or richness of birds when we assigned management treatment as a random effect. To supplement these analyses, we used the chi-square (X^2) goodness of fit test to determine if any of the observed deviations in bird abundance were significantly different from expected values for the different management treatments at SGL 33 and GLR&D (Foglia 2006).

Results

State Game Lands 33

Researchers detected between 710 and 819 individual birds representing 35-49 species per year from 2015-17 within the wire and border management zones and adjacent forest at SGL33 (Table B-1). We observed between 135 and 194 individuals representing 12-16 different bird species per year within the wire management zone and an additional 211-292 individuals ranging from 14-19 bird species per year within the border management zone of the ROW (Table B-1). Chestnut-sided warbler, field sparrow, eastern towhee, common yellowthroat, gray catbird, and indigo bunting were the most abundant birds within the wire and border management zones at SGL33 (Table B-2). Abundance and species richness of breeding birds was not significantly different ($p > 0.05$) among the different wire zone sections during the final two years of an IVM cycle in 2015 and 2016 (Tables B-3 and B-4). After initiating a new 4-6 year cycle with extensive IVM in the late summer and early fall of 2016, the abundance of birds in 2017 was significantly lower than expected ($X^2 = 15.1$, $p < 0.01$) on the mowing only section compared to other sections within the wire management zone at SGL 33 and the overall abundance of birds within the wire management zone was at a three year low in 2017 (Tables B-1 and B-5, Figure B-1). Similarly, the abundance of breeding birds within the border management zone saw a significant decline (estimate = -0.065, $p < 0.001$) during 2017 compared to in 2015 and 2016 (Table B-1, Figure B-2). The section of ROW without borders contained the lowest abundance and richness of breeding birds compared to the other five sections at end of an IVM cycle in spring and early summer 2016 (Table B-4). Additionally, the no border section of ROW had the lowest bird abundance and richness of all sections at the onset of a new IVM cycle in spring and early summer 2017, with the exception of the mowing only section that had complete removal of all vegetation within the wire zone and reduction of the border zone during late summer and early fall 2016 (Table B-5).

We identified 30 species of birds displaying evidence of breeding including six possible, five probable, and 19 confirmed breeding species within the wire and border management zones at SGL33 during 2016 and 2017 (Table B-6). Sections of the ROW without borders and mowing only sections contained the lowest number of bird species displaying evidence of breeding both at the end and beginning of a new IVM cycle in 2016 and 2017, respectively (Tables B-7 and B-8). Of the 19 confirmed breeding bird species, researchers located and followed activity of 47 nesting attempts (23 located in the wire and 24 in the border management zones) by 11 different bird species during 2016 and 61 nesting attempts (35 located in the wire and 26 in the border management zones) by 15 different bird species during 2017 (Tables B-9 and B-10). Overall nesting success was higher at a 49% success rate (52% success rate in the wire management zone and 46% success rate in the border management zone) during the end of the IVM cycle in 2016 compared to 36% success rate (34% success rate in the wire management zone and 38.5% success rate in the border management zone) following the onset of a new IVM cycle in 2017 (Tables B-9 and B-10). Only a single incidence of nest parasitism by brown-headed cowbird occurred within a host American robin nest of a total 108 possible nesting attempts initiated by all species combined during 2016 and 2017.

Green Lane Research and Demonstration Area

Researchers detected between 473 and 616 individual birds representing 42-46 species per year from 2015-17 within the wire and border management zones, PPL ROW, and adjacent forest at the GLR&D (Table B-11). We observed between 136 and 166 individuals representing 16-21 different bird species per year within the wire management zone and an additional 15-48 individuals ranging from 6-11 bird species per year within the border management zone of the ROW (Table B-11). Field sparrow, indigo bunting, common yellowthroat, American goldfinch, and eastern towhee were the most abundant birds within the wire and border zones on the GLR&D ROW (Table B-12). The low volume stem and foliar herbicide application and high volume foliar herbicide application sections within the wire management zone contained significantly higher abundance of birds than expected ($X^2 = 50.6$, $p < 0.001$) compared to the hand cutting, mowing, and mowing with herbicide application sections (Table B-13, Figure B-3). Additionally, the low volume stem and foliar herbicide application and high volume foliar herbicide application sections within the wire management zone had the highest species richness of birds for each of the three survey years (Table B-13). The border management zone saw a significant decline in bird abundance (estimate = -0.04, $p < 0.001$) and reduction in number of species present during the 2017 breeding season as compared to 2015 and 2016 (Table B-11, Figure B-4).

Discussion

Early successional habitats and components of their ecosystems (e.g., breeding bird communities) are dramatically declining throughout the United States (King and Byers 2002, Schlossberg and King 2015). In the northeastern United States, bird species using early successional vegetation are declining faster than other groups such as forest or wetland birds. Declines in early successional habitat and their associated communities are largely due to changing land use practices and the suppression of natural disturbances that create this type of ecosystem. Powerline ROW comprise approximately 2-3 million ha in the United States (Russell et al. 2005). In terms of managed, early successional habitat, electrical utilities can manage more land area than national parks; in New York alone electric utilities manage nine times as much early successional habitat as the land managed by all federal, state, and non-governmental organizations (Confer and Pascoe 2003). Artificial disturbances that create and maintain vegetation in a state of permanent early succession such as utility line ROW have been documented as being valuable bird habitat and serve as nesting areas for a diversity of avian species (King and Byers 2002, Confer and Pascoe 2003, Forrester et al. 2005, Bulluck and Buehler 2006, Yahner et al. 2004, 2005, and 2008). Previous study of bird communities at SGL33 and GLR&D have shown from the early 1980's through 2006 that anywhere between 31-44 species of birds have utilized the ROW per year (Bramble et al. 1984 and 1994, Yahner et al. 2003 and 2008). During 2016-17, 29 species displayed evidence of breeding within the wire and border management zones at SGL 33 and from 2015-17 we detected between 16-21 species within the wire and 6-11 bird species within the border management zones at GLR&D. The most abundant birds on the two ROW included early successional habitat obligates such as chestnut-sided warbler, common yellowthroat, eastern towhee, field sparrow, gray catbird, and prairie warbler. Since artificial disturbances not created solely for natural resource conservation now make up a majority (approximately 80%) of these early successional habitats, it is important to make informed decisions about how these areas are created and managed (Forrester et al. 2005, Bulluck and Buehler 2006, Schlossberg and King 2015). Therefore, ROW maintained using IVM such as those at SGL 33 and GLR&D will be vital to and can be used as examples of early successional habitat management for bird conservation.

Since the onset of the modern environmental movement in the 1950's and further evidenced in 1962 by Rachel Carson's example of the effects of the pesticide Dichlorodiphenyltrichloroethane (DDT) on bird productivity in her publication *Silent Spring*, use of certain herbicides and pesticides to increase agricultural production, manage insect populations, or manage vegetation continually has been scrutinized by environmental and regulatory agencies as well as the general public. In response to public concern - predominantly from hunters - about the impact of vegetation management practices on wildlife habitat within electric transmission ROW, scientific study of the effects of different types of management began at SGL 33 in 1953 and has been accompanied by investigation of the influence IVM has on flora and fauna at GLR&D since

1987 (sites.psu.edu/transmissionlineecology). The effects of herbicide use often are equated to but should not be misconstrued or confused with the effects of pesticide use and the possible harm pesticides may demonstrate toward non-target plants and animals. Throughout the history of the research conducted at SGL 33 and GLR&D, numerous studies have demonstrated that proper use of herbicides via IVM has been compatible with and even beneficial to plant and animal communities (Bramble and Byrnes 1983, Bramble et al. 1984, 1997, and 1999, Yahner et al. 2001a, 2001b, and 2002, Yahner and Hutnick 2005, Russo et al. *In Review*). In particular, Bramble et al. (1984) and Yahner et al. (2002) emphasized the benefits of IVM and positive response of bird communities to sections of ROW maintained in an early successional state with the proper use of herbicides. Our current research findings from 2015-17 further indicate support for IVM that incorporates the proper use of herbicides. Ultra low volume foliar and high volume foliar application on sections of GLR&D contained the highest abundance and richness of breeding birds. Additionally, sections of ROW at SGL 33 managed using herbicides were comparable or more beneficial to bird communities in terms of abundance, species richness, indices of productivity, and nesting success than sections maintained via mechanical treatments both at the end of a four year IVM cycle (2016) and during the first breeding season post treatment (2017). On both SGL 33 and GLR&D, the most abundant bird species were either insectivores (barn swallow, chestnut-sided warbler, common yellowthroat, indigo bunting, and prairie warbler) or omnivores (eastern towhee, field sparrow, and gray catbird); further clarifying the differences in effects of insecticides versus herbicides and supporting IVM incorporating the proper use of herbicides along ROW.

The wire zone - border zone IVM approach was applied at SGL33 and GLR&D in the mid-1980's. The zone located directly under transmission lines (wire zone) is managed to maintain a plant community comprised of grass, forbs and low shrubs in order to minimize reinvasion of tall-statured trees and shrubs that could possibly interfere with electrical transmission lines (Figure I-1). Either or both sides of the wire zone adjoin a narrow border zone dominated by of low- to medium-sized shrubby vegetation before the ROW transitions to natural forest. Past research on the two study locations indicated that within the ROW, nearly four times as many birds were observed in the shrubby border zones as in the wire zones (Yahner et al 2002 and 2003). During 2015-17, we detected more individuals and more bird species within the border compared to the wire zone for all three years of surveys at SGL 33. Additionally, avian productivity in the form of number of successful nests was comparable between border and wire zones (11 versus 12 nests and 10 versus 12 nests in 2016 and 2017, respectively) despite the wire zone being 25 feet wider than the border zone in 2016 and more than three times the total area of the border zone in 2017. In 2016 sections of ROW at SGL 33 that contained no borders had the lowest number of individual birds, species richness, possible through confirmed bird productivity, and number of successful nests compared to the other five management types that contain border zones. The same was true in 2017 with the exception of mowing only management section which was the least beneficial to breeding birds following extensive treatment of the ROW at SGL 33 in the fall of 2016. Hence, the border zone is a very important component of IVM as it adds habitat for bird species that require a combination or mix of herbaceous vegetation, shrubs, and sapling tree species. A concerted effort needs to be made to retain borders and border vegetation especially with the new federal safety regulations requiring increased clearance between vegetation and the electrical transmission lines and with the introduction and spread of spotted lanternfly (*Lycorma delicatula*) into southeastern Pennsylvania.

In addition to being a vital component of ROW management for bird species requiring shrubby habitat, the border zone can help minimize the impacts of management conducted within the wire zone at the beginning of an IVM cycle. Bramble et al. (1992) and (1994) noted significant declines in bird populations following IVM at both SGL 33 and GLR&D. They also suggested that border zones were responsible for the retention of large and diverse bird populations on the ROW, as the wire zone - border zone method of IVM allowed for retention of shrub cover as the dominant vegetation component within the borders despite extensive changes to vegetation within the wire zone post management (Bramble et al. 1992 and 1994). We also detected the fewest birds in 2017 at SGL 33 following IVM in fall 2016 as compared to the pre-treatment breeding seasons of 2015 and 2016. Beside changes in avian abundance, breeding bird productivity can fluctuate quite dramatically from year to year and the presence of border zone vegetation may help to retain birds following extensive management within the wire zone. A nesting success rate of 68% was the highest recorded at SGL 33 in 1991-92 combined, whereas Yahner et al. (2004) detected differences in nesting success rates of 39% in 2002 compared to 65% in 2003. For comparison, nesting success was 42% at GLR&D within a similar time period (2003-04) and success rates average around 50% for different managed landscapes within Pennsylvania and Maryland (Bramble et al. 1994, Yahner et al. 2005). On the ROW at SGL 33, nearly half of the nests fledged young in 2016 (49% of 47 nests; with 52% wire zone nests and 46% border zone nests) compared to 36% of 61 nests in 2017 (34% wire zone nest success and 38.5% border zone nest success). Fluctuations in breeding bird productivity and nest success have been attributed to many causes including ambient temperature differences between years that alter plant phenology (availability of nest cover) and nest chronology and varying population levels of different nest predators (Pettingill 1985, Yahner et al. 2004). However, differences in both wire zone and border zone nest success rates, plus overall nest success rates between 2016 and 2017 at SGL 33 likely were due to reduction of available nest cover with changing vegetation characteristics in both zones following the initiation and implementation of a new IVM cycle in the late summer and early fall of 2016. Integrated vegetation management including the wire zone - border zone method appears beneficial to early successional birds as evidenced by the continued presence of a diverse avian community throughout the history of IVM at SGL 33 since 1982 and on the GLR&D since research began in 1987. It will be important to gain insight as to how breeding bird productivity responds to changes in vegetation throughout the course of an IVM cycle (mid-cycle compared to the end or beginning), as well as track the possible long-term changes in bird populations with the recent reduction of the border zones at SGL 33 and GLR&D, plus the increasing presence of invasive and exotic defoliating insects potentially eliminating vegetation cover at GLR&D.

Table B-1. Abundance and species richness of breeding birds from 2015-17 within the wire and border management zones and adjacent forest at State Game Lands 33, Centre County, Pennsylvania.

	2015		2016		2017	
	# Birds	**# Species**	**# Birds**	**# Species**	**# Birds**	**# Species**
Wire Zone	153	12	194	16	135	14
Border Zone	292	14	270	19	211	17
Adjacent Forest	314	30	355	36	364	47
TOTAL	759	35	819	42	710	49

Table B-2. Most abundant bird species detected from 2015-17 within the wire and border management zones at State Game Lands 33, Centre County, Pennsylvania.

Species	**Wire Zone** # Birds	**Border Zone** # Birds	**Total**
Chestnut-sided Warbler (*Setophaga pensylvanica*)	40	260	300
Field Sparrow (*Spizella pusilla*)	151	65	216
Eastern Towhee (*Pipilo erythrophthalmus*)	58	135	193
Common Yellowthroat (*Geothlypis trichas*)	119	49	168
Gray Catbird (*Dumetella carolinensis*)	22	111	133
Indigo Bunting (*Passerina cyanea*)	35	70	105

Table B-3. Abundance and species richness of breeding birds in 2015 on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW	Wire Zone		Border Zone		Totals	
	# Birds	# Species	# Birds	# Species	# Birds	# Species
LVB (2 Sections)	29	8	49	9	78	11
ULVF (3 Sections)	27	7	65	7	92	10
HVF (3 Sections)	27	6	81	9	108	10
HC (2 Sections)	40	9	35	10	75	15
M (2 Sections)	30	5	62	10	92	10

Table B-4. Abundance and species richness of breeding birds in 2016 on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), control with no border (CNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW	Wire Zone		Border Zone		Totals	
	# Birds	# Species	# Birds	# Species	# Birds	# Species
LVB (2 Sections)	23	6	34	10	57	10
ULVF (3 Sections)	32	10	71	11	103	13
HVF (3 Sections)	24	6	65	10	89	11
CNB (2 Sections)	54	8	--	--	54	8
HC (2 Sections)	35	11	54	13	89	15
M (2 Sections)	26	7	46	10	72	11

Table B-5. Abundance and species richness of breeding birds in 2017 on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), low volume foliar herbicide application with no borders (LVFNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW	**Wire Zone**		**Border Zone**		**Totals**	
	# Birds	**# Species**	**# Birds**	**# Species**	**# Birds**	**# Species**
LVB (2 Sections)	27	8	35	11	62	15
ULVF (5 Sections)	37	8	98	14	137	16
HVF (2 Sections)	27	8	19	6	47	9
LVFNB (2 Sections)	21	6	--	--	21	6
HC (2 Sections)	21	7	50	6	71	8
M (1 Section)	2	1	6	2	8	3

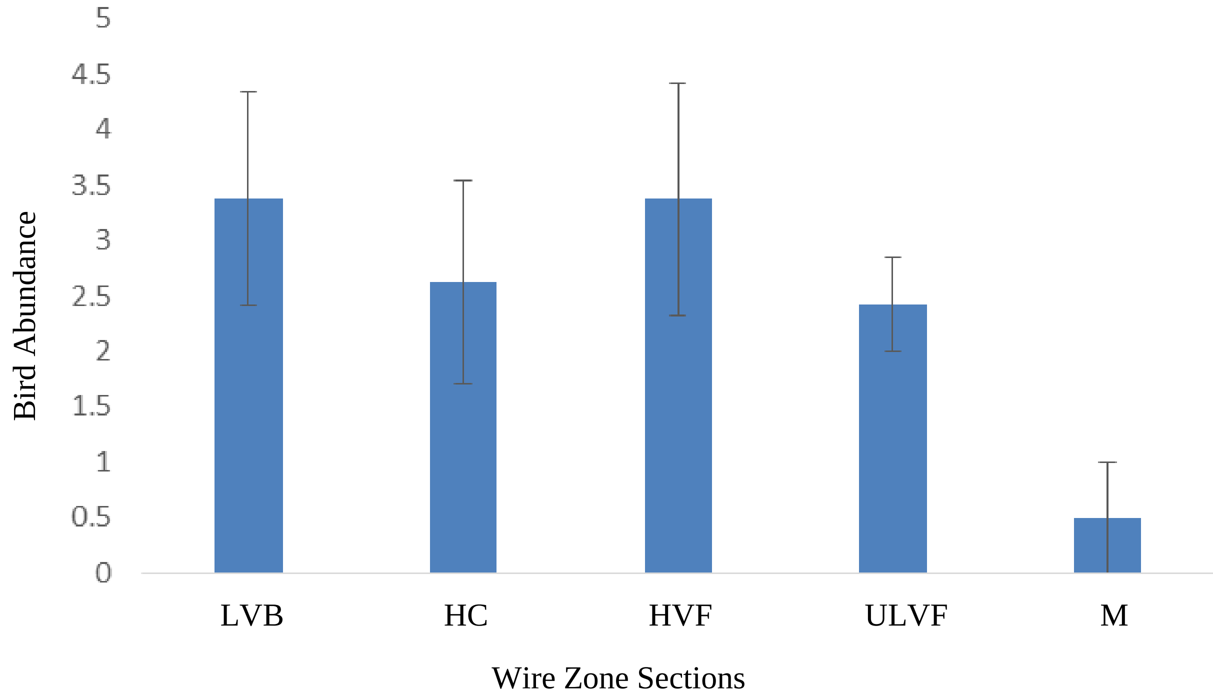

Figure B-1. Abundance of birds per survey in 2017 on the low volume basal herbicide application (LVB), low volume foliar herbicide application and ultra low volume foliar herbicide application with no borders (ULVF), high volume foliar herbicide application (HVF), hand cutting only (HC), and mowing only (M) sections within the wire management zone at State Game Lands 33, Centre County, Pennsylvania.

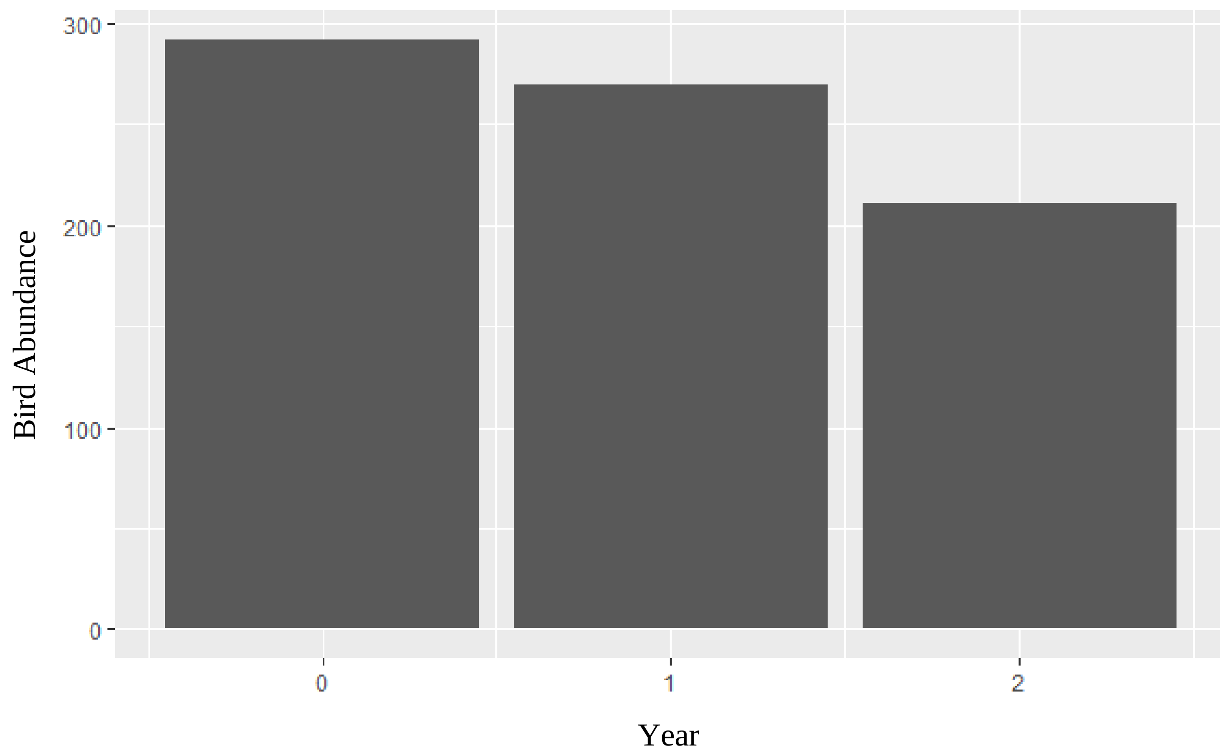

Figure B-2. Abundance of breeding birds detected during 2015 (Year 0), 2016 (Year 1), and 2017 (Year 2) within the border management zone on the Research and Demonstration Project site at State Game Lands 33, Centre County, Pennsylvania.

Table B-6. List of birds displaying possible, probable, and confirmed evidence of breeding based on Pennsylvania Breeding Bird Atlas codes within the wire and border management zones at State Game Lands 33, Centre County, Pennsylvania during 2016 and 2017.

Common and Scientific Names of Birds	**AOU Bird Code[1]**	**Breeding Status**
American Crow (*Corvus brachyrhynchos*)	AMCR	Possible
American Goldfinch (*Spinus tristis*)	AMGO	Confirmed
American Redstart (*Setophaga ruticilla*)	AMRE	Confirmed
American Robin (*Turdus migratorius*)	AMRO	Confirmed
Black-and-white Warbler (*Mniotilta varia*)	BAWW	Probable
Black-billed Cuckoo (*Coccyzus erythropthalmus*)	BBCU	Confirmed
Black-capped Chickadee (*Poecile atricapillus*)	BCCH	Possible
Blue Jay (*Cyanocitta cristata*)	BLJA	Confirmed
Brown-headed Cowbird (*Molothrus ater*)	BHCO	Confirmed
Brown Thrasher (*Toxostoma rufum*)	BRTH	Confirmed
Cedar Waxwing (*Bombycilla cedrorum*)	CEDW	Confirmed
Common Yellowthroat (*Geothlypis trichas*)	COYE	Confirmed
Chestnut-sided Warbler (*Setophaga pensylvanica*)	CSWA	Confirmed
Eastern Towhee (*Pipilo erythrophthalmus*)	EATO	Confirmed
Field Sparrow (*Spizella pusilla*)	FISP	Confirmed
Gray Catbird (*Dumetella carolinensis*)	GRCA	Confirmed
Hermit Thrush (*Catharus guttatus*)	HETH	Confirmed
Indigo Bunting (*Passerina cyanea*)	INBU	Confirmed
Mourning Dove (*Zenaida macroura*)	MODO	Possible
Northern Flicker (C*olaptes auratus*)	NOFL	Possible
Ovenbird (*Seiurus aurocapilla*)	OVEN	Confirmed

Table B-6. (continued).

Common and Scientific Names of Birds	**AOU Bird Code[1]**	**Breeding Status**
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	RBGR	Probable
Red-eyed Vireo (*Vireo olivaceus*)	REVI	Confirmed
Ruby-throated Hummingbird (*Archilochus colubris*)	RTHU	Possible
Scarlet Tanager (*Piranga olivacea*)	SCTA	Probable
Song Sparrow (*Melospiza melodia*)	SOSP	Probable
Tufted Titmouse (*Baeolophus bicolor*)	TUTI	Possible
Veery (*Catharus fuscescens*)	VEER	Probable
Wild Turkey (*Meleagris gallopavo*)	WITU	Confirmed
Wood Thrush (*Hylocichla mustelina*)	WOTH	Confirmed

[1]American Ornithologists' Union four-letter alpha codes for bird identification.

Table B-7. Number of bird species displaying possible, probable, and confirmed evidence of breeding during 2016 based on Pennsylvania Breeding Bird Atlas codes on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), control with no border (CNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW	# Bird Species Possible	# Bird Species Probable	# Bird Species Confirmed	Total # of Bird Species
LVB (2 Sections)	4	3	8	15
ULVF (3 Sections)	3	4	8	15
HVF (3 Sections)	4	1	10	15
CNB (2 Sections)	3	1	5	9
HC (2 Sections)	9	3	5	17
M (2 Sections)	2	5	5	12
Combined All Sections	6	5	15	26

Table B-8. Number of bird species displaying possible, probable, and confirmed evidence of breeding during 2017 based on Pennsylvania Breeding Bird Atlas codes on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), low volume foliar herbicide application with no borders (LVFNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW	# Bird Species Possible	# Bird Species Probable	# Bird Species Confirmed	Total # of Bird Species
LVB (2 Sections)	9	0	8	17
ULVF (5 Sections)	6	1	11	18
HVF (2 Sections)	6	0	5	11
LVFNB (2 Sections)	2	1	4	7
HC (2 Sections)	3	2	7	13
M (1 Section)	1	0	4	5
Combined All Sections	6	2	17	25

Table B-9. Distribution and outcome of attempted nesting activity by breeding birds during 2016 on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), control with no border (CNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW or Management Zone	# Nests (# Wire, # Border)	# Successful Nests	# Preyed Nests	# Nesting Bird Species
LVB (2 Sections)	7 (2,5)	4	3	6
ULVF (3 Sections)	7 (3,4)	5	2	4
HVF (3 Sections)	14 (4,10)	5	9	8
CNB (2 Sections)	6 (6,0)	2	4	4
HC (2 Sections)	6 (4,2)	4	2	5
M (2 Sections)	7 (4,3)	3	4	3
WIRE	23	12	11	7
BORDER	24	11	13	10
TOTAL	47	23	24	11

Table B-10. Distribution and outcome of attempted nesting activity by breeding birds during 2017 on the low volume basal herbicide application (LVB), ultra low volume foliar herbicide application (ULVF), high volume foliar herbicide application (HVF), low volume foliar herbicide application with no borders (LVFNB), hand cutting only (HC), and mowing only (M) sections within the wire and border management zones of the right-of-way (ROW) at State Game Lands 33, Centre County, Pennsylvania.

Section of ROW or Management Zone	# Nests (# Wire, # Border)	# Successful Nests	# Preyed Nests	# Nesting Bird Species
LVB (2 Sections)	8 (3,5)	4	4	6
ULVF (5 Sections)	23 (13,10)	7	16	8
HVF (2 Sections)	7 (5,2)	2	5	3
LVFNB (2 Sections)	5 (5,0)	3	2	3
HC (2 Sections)	15 (6,9)	5	10	8
M (1 Section)	3 (2,1)	1	2	3
WIRE	35	12	23	9
BORDER	26	10	16	12
TOTAL	61	22	39	15

Table B-11. Abundance and species richness of breeding birds from 2015-17 within the wire and border management zones, Pennsylvania Power and Light electric utilities (PPL) right-of-way (ROW), and adjacent forest at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania.

	2015		2016		2017	
	# Birds	# Species	# Birds	# Species	# Birds	# Species
Wire Zone	136	19	154	21	166	16
Border Zone	48	11	42	11	15	6
PPL ROW	67	19	43	14	114	22
Adjacent Forest	282	35	234	39	321	42
TOTAL	533	42	473	46	616	45

Table B-12. Most abundant bird species detected from 2015-17 within the wire and border management zones at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania.

Species	Wire Zone	Border Zone	Total
	# Birds	# Birds	
Field Sparrow (*Spizella pusilla*)	143	17	160
Indigo Bunting (*Passerina cyanea*)	61	15	76
Common Yellowthroat (*Geothlypis trichas*)	64	11	75
American Goldfinch (*Spinus tristis*)	48	0	48
Eastern Towhee (*Pipilo erythrophthalmus*)	13	15	28
Barn Swallow (*Hirundo rustica*)	25	0	25
Prairie Warbler (*Setophaga discolor*)	12	10	22
Northern Cardinal (*Cardinalis cardinalis*)	8	12	20
Gray Catbird (*Dumetella carolinensis*)	9	7	16

Table B-13. Abundance and species richness of breeding birds from 2015-17 on the ultra low volume foliar (ULVF), high volume foliar herbicide application (HVF), hand cutting (HC), mowing (M), and mowing cut stubble application (MCS) sections within the wire management zone of the right-of-way (ROW) at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania.

Section of ROW	2015		2016		2017	
	# Birds	# Species	# Birds	# Species	# Birds	# Species
ULVF	46	14	39	12	37	10
HVF	44	11	45	14	42	10
HC	13	5	32	7	33	9
M	25	7	22	5	27	5
MCS	8	4	16	8	27	7

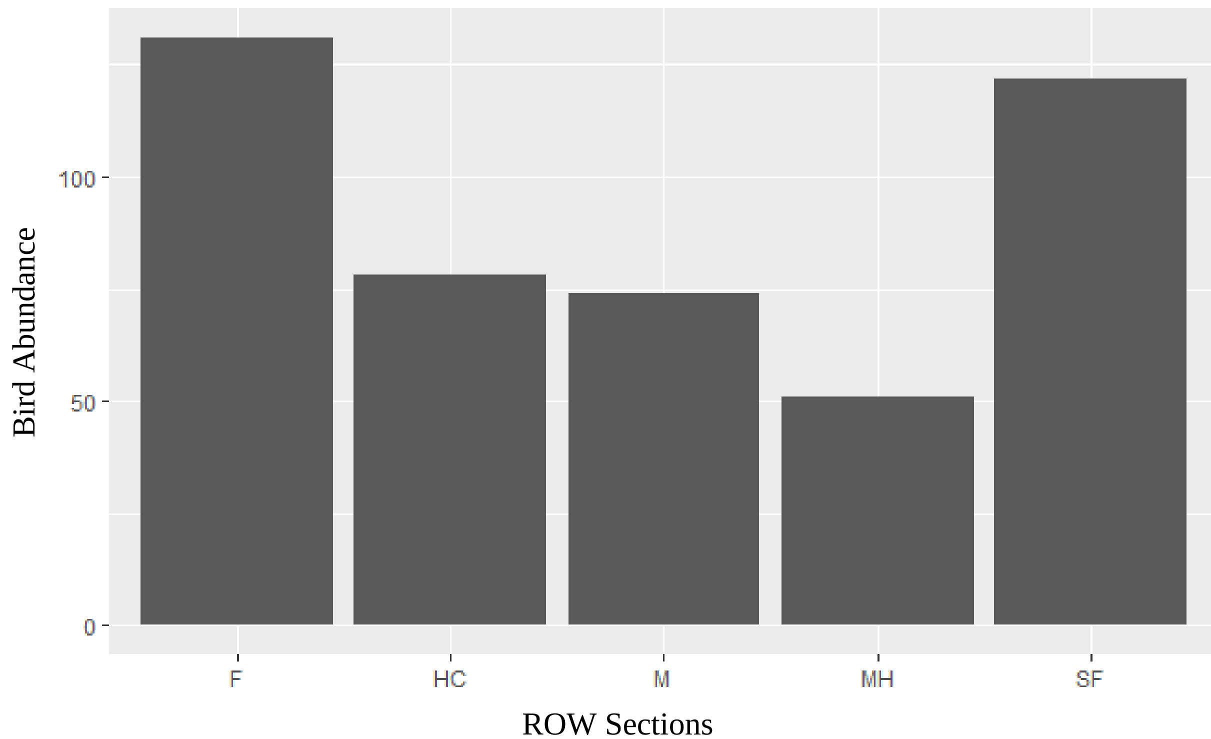

Figure B-3. Abundance of breeding birds from 2015-17 on the low volume stem and foliar herbicide application (SF; now termed ultra low volume foliar; ULVF), high volume foliar herbicide application (F; now HVF), hand cutting (HC), mowing (M), and mowing with herbicide application (MH; now termed mowing cut stubble; MCS) sections within the wire management zone of the right-of-way (ROW) at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania.

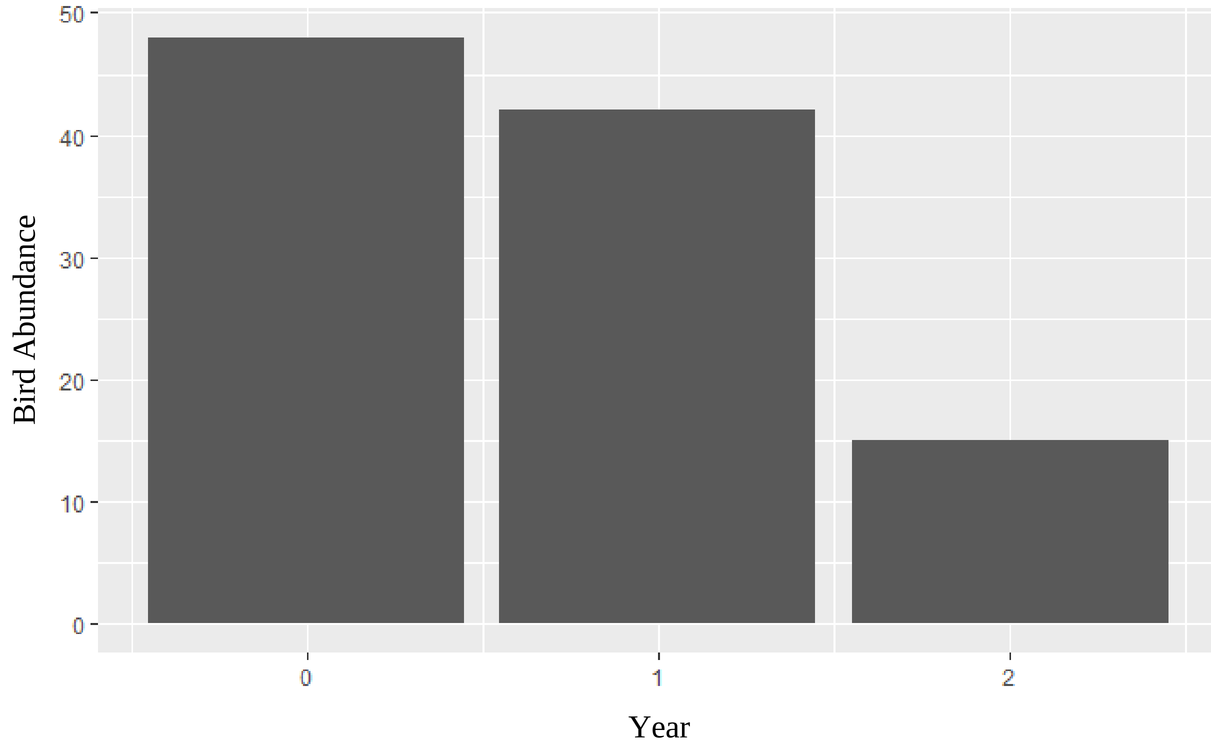

Figure B-4. Abundance of breeding birds detected during 2015 (Year 0), 2016 (Year 1), and 2017 (Year 2) within the border management zone of the right-of-way (ROW) at the Green Lane Research and Demonstration Area, Montgomery County, Pennsylvania.

POLLINATORS

Project goals and objectives for 2017

Goals

1. State Game Lands (SGL) 33: To collect flower-visiting insects, and then compare the diversity of bees among the six different plots, which represent four different vegetation management strategies.

2. SGL 33: To compare pre-treatment with post-treatment bee populations (2016 vs 2017).

3. Green Lane Research and Demonstration Area (GLR&D): To collect flower-visiting insects, and then compare the diversity of bees among the five different plots, each representing five different vegetation management strategies.

Objectives

To examine the potential differences in bee populations among different plots and vegetative treatments, and to provide the project's stakeholders with an analysis of bee abundance, richness, and diversity at SGL 33 and at GLR&D, that will assist in making management recommendations for the future.

Methods

Overview of SGL 33 and GLR&D study sites

Please note that in this portion of our report, legacy treatment names are used. This usage is an artifact of study design and database development. For bee sampling, a small subset of total treatments were selected as follows at SGL 33 (Appendix A):

F2 (Foliage spray; Legacy site name) = High volume foliar (HVF); HVF treatment in 2016
SF2 (Stem foliar; Legacy site name) = Ultra low volume foliar (ULVF); HVF treatment in 2016
MH3 (Mow plus herbicide; Legacy site name) = Mow cut stubble (MCS); ULVF treatment in 2016
MH1 (Legacy site name) = Mow cut stubble (MCS); ULVF treatment in 2016
BLV3 (Basal Low Volume; Legacy site name) = Low volume basal (LVB); LVB treatment in 2016
HC1 (Hand cut;Legacy site name) = Hand cutting (HC); HC treatment in 2016

At GLR&D, a small subset of total treatments were selected as follows:

F1 (Foliage spray; Legacy site name) = High volume foliar (HVF); HVF treatment in 2014
M1 (Mowing; Legacy site name) = Mowing (M); M treatment in 2014
MH1 (Mowing plus herbicide; Legacy site name) = Mow cut stubble (MCS); MCS treatment in 2014
SF2 (Stem foliar; Legacy site name) = Ultra low volume foliar (ULVF); ULVF treatment in 2014
HC2 (Hand cut; Legacy site name) = Hand cutting (HC); HC treatment in 2014

Bee sampling

Hymenoptera surveys were conducted for two consecutive days per month, for four months (May-August 2017). To account for potential bias caused by sampling in the morning versus in the afternoon, the order of visiting sites alternated between the two monthly collection dates. Bee survey sites were situated consecutively along the ROW, allowing for collectors to rotate between one set of three sites in the morning, and one set of the other three sites in the afternoon. On each field day, each collector used aerial nets and aspirators to collect Hymenoptera (or suspected Hymenoptera) from flowering vegetation within the 50m x 25m active collection area at each of the survey sites. For each field day, one net hour was spent at each of the six survey sites. “Net hours” are the total amount of time spent sweep net sampling at one site by all collectors (e.g. one collector netting at one site for one hour = two collectors netting at one site for 30 minutes). A total of eight net hours were spent at each of the survey sites—four hours of morning collections, and four hours of afternoon collections.

SGL 33 2017 sampling schedule

The SGL 33 sampling schedule is located in Figure P-1.

SGL 33 field data sheets

For 2017, net-collectors were not asked to identify flowering plants in the field; rather they were asked to photograph flowering plants, and to upload their photos to the project’s Box webpage. Original data sheets are available upon request.

SGL 33 sweep net sample processing and specimen sorting

All sample processing and sorting was performed by one entomologist (Dr. Stout) and two assistants (John Berger and Brad Ross), from September 19, 2016 to February 14, 2017. Bees were pinned, then sorted by Site (e.g. SGL 33), Plot (e.g. F2), Month, and Time of Day (AM or PM). Each Site/Plot/Month/TOD group of bees was counted, and a corresponding number of Site Labels and Identifier Labels were created. For each group, all information from both labels was entered into a separate Excel worksheet. It was only after all of the bees were pinned and sorted that each was labeled with Site and Identifier Labels. This sequence of actions ensured that numerical sequences of Identifier Label numbers were assigned to specific groups of bees, which helped to ensure accuracy.

SGL 33 specimen identification and taxonomic effort

All identifications were performed from December 19, 2017 to May 4, 2018. All non-Hymenoptera specimens were identified to Family (Genus or Species when such identifications could be easily made) by John Berger, Brad Ross, and Dr. Stout in Room 102 of the Headhouse III building, on the University Park campus of the Pennsylvania State University. Bumble bees were identified to Species by Dana Roberts in Room 130, the Urban Lab at University Park. Three bumble bees and most of the non-bumble bees were identified to Species or Species Complex by Dr. Stout at her lab in State College, Pennsylvania. Sam Droege, of the USGS Patuxent Wildlife Research Center in Beltsville, Maryland, verified Roberts' and Stout's identifications, and identified the most difficult bees to Species (e.g. *Lasioglossum* sp. sweat bees). Some bees were identified only to Species Complex (e.g. *Hylaeus affinis/modestus*), Subgenus (e.g. *Andrena (Trachandrena)* sp.) or to Genus until additional expert identifications could be made (e.g. *Sphecodes* sp.).

SGL 33 data entry

Once specimens were identified, the taxon, the initials of the Identifier, and any identification notes, were added to the corresponding Specimen ID# in the database. All data entry, editing, and analysis was completed on June 24, 2018.
Note: The same SGL 33 six plots that were surveyed in 2016 were surveyed in 2017. These six plots are: F2, SF2, MH3, MH1, BLV3, and HC1.

GLR&D field and lab methods

GLR&D field methods for 2017 were nearly identical to those of SGL 33 in 2017, with the following exceptions described below.

GLR&D 2017 sampling schedule

The GLR&D sampling schedule is located in Figure P-2.

GLR&D survey plots

There were five plots surveyed in 2017, all of which were located in Marlborough Township, Montgomery County, Pennsylvania (Appendix A):

1. F1 - Hydraulic Foliar:

   Vegetative treatment: hydraulic equipment delivers a high-volume application of a water-based broad-leaf herbicide to leaves.
   Approximate N border of plot: 40.37104247, -75.44385551

2. MH1 - Mow with Herbicide:

   Vegetative treatment: mechanical mowing of vegetation, followed by an application of an oil-based herbicide to woody cuttings.
   Approximate center of plot: 40.37020811, -75.44336730

3. M1 - Mow:

   Vegetative treatment: mechanical mowing and mulching of vegetation, without herbicide application.
   Approximate center of plot: 40.36962206, -75.44296912

4. SF2 - Stem Foliar:

   Vegetative treatment: nozzle applicator selectively applies an ultra-low volume of an oil-based, broad-leaf herbicide to leaves.
   Approximate N border of plot: 40.36003333, -75.43740361

5. HC2 - Hand Cut:

   Vegetative treatment: targeted cutting of woody vegetation, without herbicide application.
   Approximate N border of plot: 40.35873333, -75.43667786

GLR&D sweep net collection

Hymenoptera surveys were conducted for two consecutive days per month, for three months (May - July 2017). To account for potential bias caused by sampling in the morning vs. in the afternoon, the order of visiting plots alternated between the two monthly collection dates. For example: 26May 2017: PM - plots 4, 5, 1, 2, 3 then for 27May 2017: AM - plots 1, 2, 3, 4, 5. For each field day, one net hour was spent at each of the five survey plots. For the 2017 field season, a total of six net hours were spent at each of the plots - three hours of morning collections, and three hours of afternoon collections.

GLR&D lab methods

Green Lane Research & Demonstration Area lab methods were identical to those of SGL33, as Green Lane bees were processed and identified concurrently with SGL33 bees.

Results for SGL 33 from 2017

Bee families

In most of the world, "bees" are a group of insects comprised of six Hymenoptera Families:

- Andrenidae (mining bees)
- Apidae (cuckoo/carpenter/digger bees, bumble bees and honey bees)
- Colletidae (plasterer bees, masked bees)
- Halictidae (sweat bees)
- Megachilidae (leaf-cutter bees, mason bees)
- Melittidae (oil-collecting bees. RARE.)

During the 2017 field season, all six bee Families were collected at one SGL 33 plot (F2). Five of the six bee Families were collected at the five remaining plots. Melittidae was only represented at the F2 plot.

Total abundance

In 2017, we collected and identified 1288 bees representing 110 taxa from the six SGL 33 plots. Bees from the Family Apidae comprised 52.9% of all bees collected at SGL 33 (N = 681). The common eastern bumble bee (*Bombus impatiens*) comprised 21.4% of the total collection (N = 276).

Total taxa richness

For 2017, Halictidae were the richest bee Family (35 taxa), followed by Apidae (27), Megachilidae (24), Andrenidae (17), Colletidae (6) and Melittidae (1). One bee species collected at SGL 33 represents a new record for Pennsylvania: *Nomada xanthura* (Apidae) is a wasp-like cleptoparasitic nomad bee. This bee was collected at SF2. A second potential new bee species for the state was collected at MH1 and HC1: *Sphecodes galerus* (Halictidae), which is a cleptoparasitic sweat bee. As of June 28, 2018, this record is not yet official. Tables and Pie Charts illustrating the Family abundance and taxa richness of bees per plot for the 2017 SGL 33 survey can be found in Appendix D.

SGL 33 2017 - Bees x Plot

<u>Bee families</u>

Bee taxa from the Family Halictidae outnumbered taxa from other bee Families at SF2, MH3, MH1, and HC1. The Family Apidae had the greatest number of taxa at BLV3. Taxa of Apidae and Halictidae were equally the most numerous at the F2 plot.

<u>Abundance</u>

Bee abundance (here defined as the number of bees per plot) was greatest at BLV3 (336 individual bees collected over the course of the season), and lowest at HC1 (90 individuals) (Table P-1, Figure P-3).

<u>Taxa Richness</u>

The number of bee taxa per plot was greatest at MH3 (63 taxa), and lowest at HC1 (33 taxa) (Table P-2, Figure P-4):

<u>Diversity indices</u>

Diversity Indices (DIs) are mathematical methods of characterizing the diversity of a community, beyond taxa richness. Unlike taxa richness, DIs factor in the relative abundance of each taxa. Evenness (E) is the measure of the similarity of abundances among the taxa of a community on a 0 to 1 scale; for example, a community with an equal number of individuals per taxon will have an Evenness value of 1. Evenness is an essential component of a Diversity Index. Two commonly-used DIs are the Shannon Diversity Index (H) and the Simpson's Index of Diversity (1 - D). From each of these Indices, Evenness can be calculated (e.g. Shannon's E_H and Simpson's E_D).

Shannon Diversity Index (H)

The Shannon Diversity Index (H) is a mathematical measure of diversity: it is calculated by multiplying -1 by the sum of the natural logarithms of the proportions of each taxon relative to the total number of taxa. Shannon's H accounts for both the abundance and the equitable distribution (evenness) of taxa in a community. All taxa are weighted evenly, therefore a few rare taxa can have a strong effect on the outcome.

For the total 2017 collections of bees from the SGL 33 survey plots, MH1 had the greatest value of Shannon's H (3.427), and BLV3 had the lowest (2.246). Evenness (E_H) was greatest at HC1(0.8861), and lowest at BLV3 (0.5900) (Table P-3, Figure P-5).

Simpson's Index of Diversity (1 - D)

Simpson's Index of Diversity (1 - D) is another mathematical measure of diversity. This Index represents the probability that two randomly selected individuals from one community are of different taxa. It is calculated by subtracting 1 from the sum of the squared proportions of each taxon relative to the total number of taxa. As with Shannon's H, Simpson's Index accounts for both the abundance and the evenness of taxa in a community. Unlike Shannon's H, Simpson's 1 - D places more weight on dominant and/or common taxa, therefore a few rare taxa do not have as much of an effect on the probability.

For the total 2017 collections of bees from the SGL 33 survey plots, MH1 had the greatest value of Simpson's 1-D (0.9443), and BLV3 had the lowest (0.7054). Evenness (E_D) was greatest at HC1 (0.5009), and lowest at BLV3 (0.0754) (Table P-4, Figure P-6).

SGL 33 2017 - Bees x Plot x Month

<u>Abundance</u>

The months of greatest bee abundance for each plot were May - HC1; June - MH1; July - F2; August - SF2, MH3, BLV3 (Table P-5, Figure P-7).

<u>Taxa Richness</u>

The months of greatest bee taxa richness for each plot were May - SF2, BLV3, HC1; June - F2, MH3, MH1; no plots had the greatest period of bee taxa richness in July or August (Table P-6, Figure P-8).

Results for SGL 33 - 2016 versus 2017

Vegetation management treatments were performed at SGL 33 in August 2016; therefore, 2016 collections represent a “pre-treatment” state, and 2017 collections represent a “post-treatment” state.

Bee families

2016 - All six bee Families were collected at one SGL 33 plot (MH1). Five of the six bee Families were collected at four plots, and 4 Families were collected at one plot. Melittidae was only collected at MH1.

2017 - All six bee Families were collected at one SGL 33 plot (F2). Five of the six bee Families were collected at the five remaining plots. Melittidae was only collected at F2.

Total abundance

2016 - 1056 bees representing 95 taxa from the six SGL 33 plots.

2017 - 1288 bees representing 110 taxa from the six SGL 33 plots.

Total dominant taxa

2016 - Bees from the Family Apidae comprised 44.1% of all bees collected at SGL 33 (N = 466). *Apis mellifera*, the European honey bee, comprised 21.4% of the total collection (N = 226).

2017 - Bees from the Family Apidae comprised 52.9% of all bees collected at SGL 33 (N = 681). *Bombus impatiens*, the common eastern bumble bee, comprised 21.4% of the total collection (N = 276).

Abundance per plot

Comparison of abundance of bees per plot by year (2016 and 2017) is located in Table P-7 and Figure P-9. Bee abundance was greatest at BLV3 and lowest at HC1 for both years.

Taxa richness

Comparison of taxa richness per plot by year (2016 and 2017) is located in Table P-8 and Figure P-10. Taxa richness was greatest at BLV3 in 2016 and MH3 in 2017, but lowest at HC1 during both years.

Diversity indices

Comparison of Shannon's Diversity and Evenness indices per plot by year (2016 and 2017) is located in Table P-9 and Figure P-11. Comparison of Simpson's Index of Diversity and Evenness per plot by year (2016 and 2017) is located in Table P-10 and Figure P-12.

Shannon's Diversity Index (H)

2016 - Shannon's Diversity Index was greatest at SF2 and lowest at HC1.
2017 - Shannon's Diversity Index was greatest at MH1 and lowest at BLV3.

Shannon's Evenness (E_H)

2016 - Shannon's Evenness was greatest at HC1 and lowest at BLV3.
2017 - Shannon's Evenness was greatest at HC1 and lowest at BLV3.

Simpson's Index of Diversity (1 - D)

2016 - Simpson's Index of Diversity was greatest at SF2 and lowest at BLV3.
2017 - Simpson's Index of Diversity was greatest at MH1 and lowest at BLV3.

Simpson's Evenness (E_D)

2016 - Simpson's Evenness was greatest at HC1, and lowest at BLV3.
2017 - Simpson's Evenness was greatest at HC1, and lowest at BLV3.

Results for GLR&D from 2017

Bee families

During the 2017 field season, five bee Families were collected at two GLR&D plots (F1, M1), four Families at two plots (MH1, SF2), and three Families at one plot (HC2). Melittidae was not represented at any of the five GLR&D plots in 2017.

Total abundance

In 2017, we collected and identified 454 bees representing 51 taxa from the five GLR&D plots. Bees from the Family Apidae comprised 82.6% of all bees collected (N = 375). *Bombus impatiens*, the common eastern bumble bee, comprised 48.5% of the total collection (N = 220).

Total taxa richness

For 2017, Apidae were the richest bee Family (16 taxa), followed by Halictidae (14), Andrenidae (10), Megachilidae (9), and Colletidae (2). Bee taxa from the Family Apidae outnumbered taxa from other bee Families at F1, M1, SF2, and HC2. The Family Halictidae had the greatest number of taxa at MH1.

One bee species collected at GLR&D represents a new record for Pennsylvania: *Melissodes apicatus* (Apidae) is a long-horned bee that is a pickerelweed specialist. Four of these bees were collected at SF2.

Tables and Pie Charts illustrating the Family abundance and taxa richness of bees per plot for the 2017 GLR&D survey can be found in Appendix E.

GLR&D 2017 - Bees x Plot

<u>Abundance</u>

Bee abundance at GLR&D was greatest at MH1 (121 individual bees collected over the course of the season) and lowest at F1 (Table P-11, Figure P-13).

<u>Taxa Richness</u>

The number of bee taxa per plot was greatest at F1 (25 taxa), and lowest at HC2 (13 taxa) (Table P-12, Figure P-14).

Diversity Indices

Shannon's Diversity and Evenness Indices

For the total 2017 GLR&D collections, F2 had the greatest value of Shannon's H (2.607) and MH1 had the lowest (1.590). Evenness (E_H) was greatest at F2 (0.810) and lowest at MH1 (0.550) (Table P-13, Figure P-15).

Simpson's Diversity and Evenness Indices

For the 2017 GLR&D bees, F2 had the greatest value of Simpson's 1-D (0.857), and MH1 had the lowest (0.619). Evenness (E_D) was greatest at F2 (0.281), and lowest at MH1 (0.146) (Table P-14, Figure P-16).

GLR&D 2017 - Bees x Plot x Month

Abundance

All GLR&D plots in 2017 had the greatest bee abundance in July (Table P-15, Figure P-17).

Taxa richness

The months of greatest bee taxa richness for each GLR&D plot in 2017 were May - F1, MH1, M1; June - SF2; July – HC2 (Table P-16, Figure P-18).

Discussion

SGL 33 2017

Table P-17 contains a summary of results for 2017 bee collections at SGL 33. Results per month are not depicted. Each plot is ranked according to its total abundance, taxa richness, Shannon's H and E_H, and Simpson's 1-D and E_D.

The greatest abundance of bees was at BLV3 - most of which were of one species, *Bombus impatiens*, the common eastern bumble bee. This bumble bee is a ubiquitous, generalist bee that is active all season long, and is known for dwelling within extraordinarily large nests.

Halictidae had the greatest richness of the six bee Families, due largely in part to its large number of "singletons" (one individual of one species). MH3 had the greatest richness, but it also had 13 *Lasioglossum* singletons, which could skew these results.

MH1 had the greatest Shannon's and Simpson's Diversity Indices of the six plots (and MH3 in very close second), which cannot be explained solely by the presence of numerous singletons. BLV3 had the lowest Diversity Indices, which could be partly due to the dominance of *B. impatiens* at this plot. Extreme outliers (e.g. one plot with hundreds of individuals of one species) affect evenness, which explain the very low values for BLV3.

Once again, the "yellow bumble bee", *Bombus fervidus*, which is listed as "Vulnerable" on the IUCN Red List of Threatened Species (iucnredlist.org), was collected, and at the same SGL 33 plot (MH3). A rare oil-collecting bee, *Macropis ciliata*, was again collected, but this time at F2. This species belongs to a family of bees that visits only loosestrife flowers. Specialist bees such as these are usually not as abundant as generalists and are especially vulnerable to threats such as habitat loss. Nine specialist bee species (per Fowler 2016a, 2016b) were collected at all six sites at SGL 33 in 2017 (Table P-18).

SGL 33 - 2016 versus 2017

More bees and more bee taxa were collected in 2017 than in 2016. As noted earlier, large social bee nests and numerous singleton species could be a factor. The apparent decline in richness at BLV3 from 2016 to 2017 could be due to the large *B. impatiens* population present there.

As demonstrated by the Shannon's and the Simpson's Diversity Indices, there was an apparent decrease in diversity at F2, SF2 and BLV3, and an apparent increase at MH3, MH1 and HC1. These inconsistent changes from pre-treatment 2016 to post-treatment 2017, coupled with the “change” of plot for some taxa collected (e.g. *Macropis ciliata* at MH1 in 2016, then at F2 in 2017) suggest that bees “shuffled” among plots as needed.

It is interesting to note the apparent shift in dominant taxa per plot from 2016 to 2017. In 2016, *Apis mellifera*, the European honey bee, was the dominant taxon for five of the six plots. In 2017, *A. mellifera* was not even collected at three of the six plots, and was not the dominant taxon at the three plots at which it was collected. For 2017, each plot had its own unique dominant taxon: *Bombus bimaculatus*, the two-spotted bumble bee (F2), *Andrena virginiana*, the Virginia mining bee (SF2), *Ceratina dupla*, the doubled small carpenter bee (MH3), *Lasioglossum cressonii*, Cresson’s Dialictus sweat bee (MH1), *Bombus impatiens*, the common eastern bumble bee (BLV3), and *Augochloropsis metallica fulgida*, a green metallic sweat bee (HC1). *Andrena virginiana* was the dominant taxon for SF2 in 2016 and again in 2017.

GLR&D 2017

Table P-19 contains a summary of the results for 2017 bee collections at GLR&D. Results per month are not depicted. Each plot is ranked according to its total abundance, taxa richness, Shannon’s H and E_H, and Simpson’s 1-D and E_D.

Bombus impatiens was the dominant taxon for all 5 plots at GLR&D. Three specialist bees were collected at three sites at GLR&D in 2017 (Table P-20).

Based solely on our expectations from the 2016 data from SGL 33, the results for GLR&D were surprising. However, in the field, F1 and MH1 consistently appeared to have more diverse assemblages of flowering plants than the other plots - especially SF2 and HC2 - which may simply explain the greater bee abundance (MH1) and the greater bee richness and diversity (F1) of these two plots, compared to the other three.

Recommendations

Bee bowls

Timed, effort-based net-collecting was used at each plot to ensure the collection of quantitative data. Net-collectors were instructed to collect all insects visiting flowers, but large bees were prevalent in the collections, which could be due to nests present at the plots, and also due to collector bias toward large taxa (Wagner et al 2014). Bee bowl collections supplement net-collections as they are not vulnerable to this same bias. In 2016, bee bowl collections were performed as a "test run" for one 24-hour period, and at one site that was not within a treatment area. Because of the small sample size and lack of reps, site diversity and treatment effects could not be gleaned from the bowl collection data. However, four bee species were collected using bee bowls that were not present in the net-collections, so the use of bee bowl collections should be considered in the future.

SGL 33 and GLR&D sweep net collection

Time and personnel constraints resulted in a total of 6 net hours of bee collections at GLR&D for 2017. Since collector effort was not equal to that of SGL 33, direct comparisons of bee diversity for the same treatments used at SGL 33 and GLR&D cannot be made. Future GLR&D bee collections should employ the same schedule, with the same net hours, as SGL 33.

Given the results of our 2016-2017 SGL 33 bee collections, plus the results of our 2017 GLR&D collections, "treatment effects" on bee abundance, richness and diversity are not readily apparent. Interpretation of the results is especially difficult because these are uncharted waters. Dozens of studies on bee diversity at transportation corridors and utility rights-of-way have been done, but none before have compared bee populations with the different vegetation management methods used at these clearings, nor have any previous studies attempted to elucidate how these different methods may directly or indirectly affect bees.

Which treatment is best for bees?

With our 2016 and 2017 bee surveys at SGL 33 and GLR&D, and with future studies at these and additional sites, we are laying a foundation of knowledge that will one day help to answer this question.

<u>31 May - 17 Aug 2017 (12 weeks)</u>

<u>4 Sample Periods</u>

WEEK 1: 31 May, 1 June
WEEK 5: 29 - 30 June
WEEK 9: 24 - 25 July
WEEK 12: 16 - 17 August

Figure P-1. Field sampling schedule at SGL 33 for 2017.

<u>26 May - 28 July 2017 (10 weeks)</u>

<u>3 Sample Periods</u>

WEEK 1: 26 - 27 May
WEEK 6: 26 - 27 June
WEEK 10: 27 - 28 July

Figure P-2. Field sampling schedule at GLR&D for 2017.

Table P-1. Abundance of bees per plot at SGL 33 for 2017.

2017 SGL 33 BEE ABUNDANCE

Plot	(# Individuals)
F2	197
SF2	266
MH3	256
MH1	143
BLV3	336
HC1	90

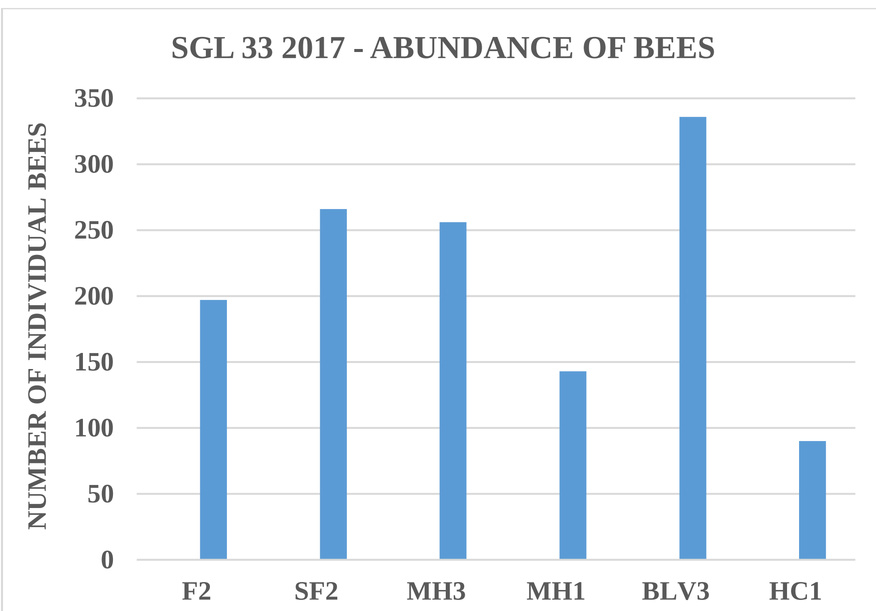

Figure P-3. Abundance of bees per plot at SGL 33 for 2017.

Table P-2. Taxa richness of bees per plot at SGL 33 for 2017.

2017 SGL 33 BEE RICHNESS

Plot	(# of Taxa)
F2	41
SF2	41
MH3	63
MH1	51
BLV3	45
HC1	33

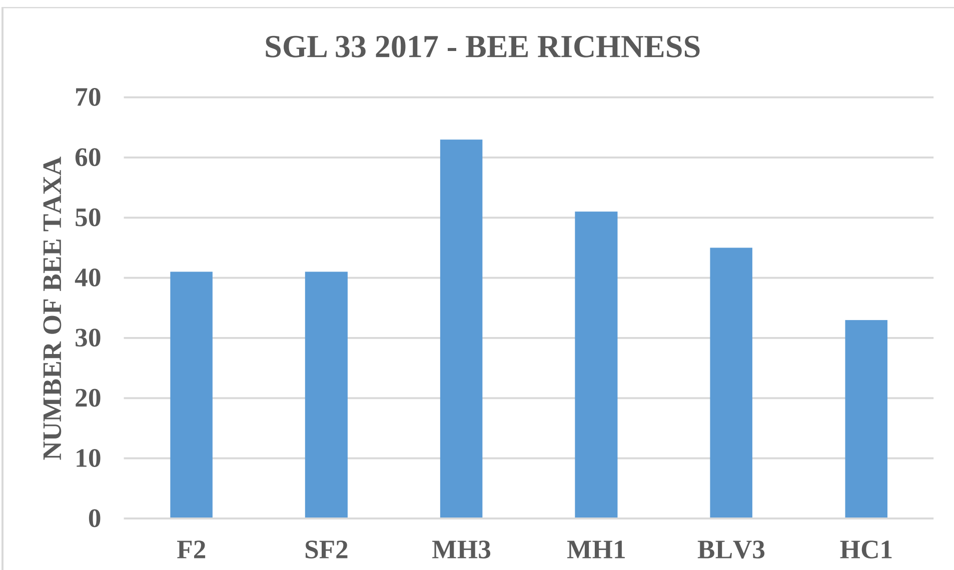

Figure P-4. Taxa richness of bees per plot at SGL 33 for 2017.

Table P-3. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at SGL 33 for 2017.

2017 SGL 33 - SHANNON DIVERSITY

	2017 Diversity	2017 Evenness
F2	2.698	0.726
SF2	2.792	0.752
MH3	3.421	0.826
MH1	3.427	0.872
BLV3	2.246	0.590
HC1	3.098	0.886

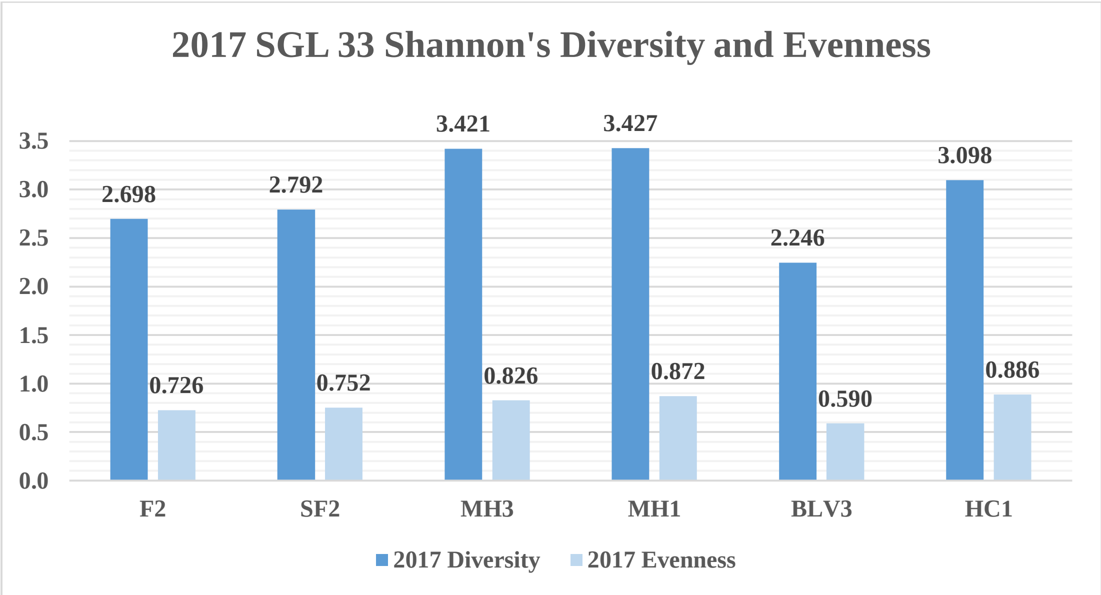

Figure P-5. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at SGL 33 for 2017.

Table P-4. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at SGL 33 for 2017.

2017 SGL 33 - SIMPSON DIVERSITY

	2017 Diversity	2017 Evenness
F2	0.854	0.168
SF2	0.897	0.238
MH3	0.940	0.263
MH1	0.944	0.352
BLV3	0.705	0.075
HC1	0.940	0.501

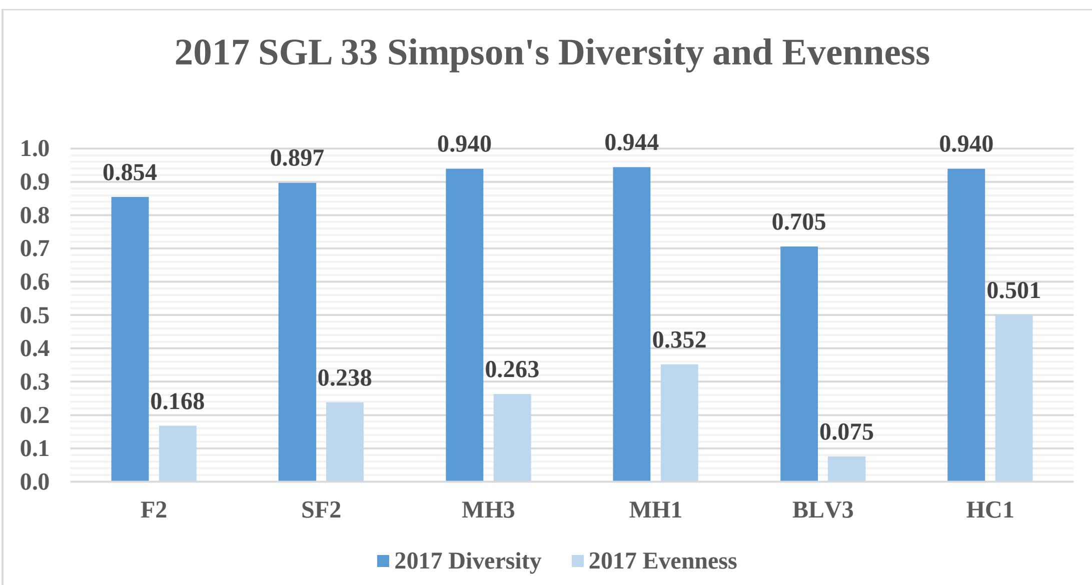

Figure P-6. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at SGL 33 for 2017.

Table P-5. Bee abundance per plot by month at SGL 33 for 2017.

SGL33 2017 - BEE ABUNDANCE PER PLOT BY MONTH (NUMBER OF INDIVIDUAL BEES)						
	F2	SF2	MH3	MH1	BLV3	HC1
MAY	33	56	59	55	62	**32**
JUNE	45	29	70	**75**	46	14
JULY	**96**	65	47	6	65	20
AUGUST	23	**117**	**80**	7	**163**	24

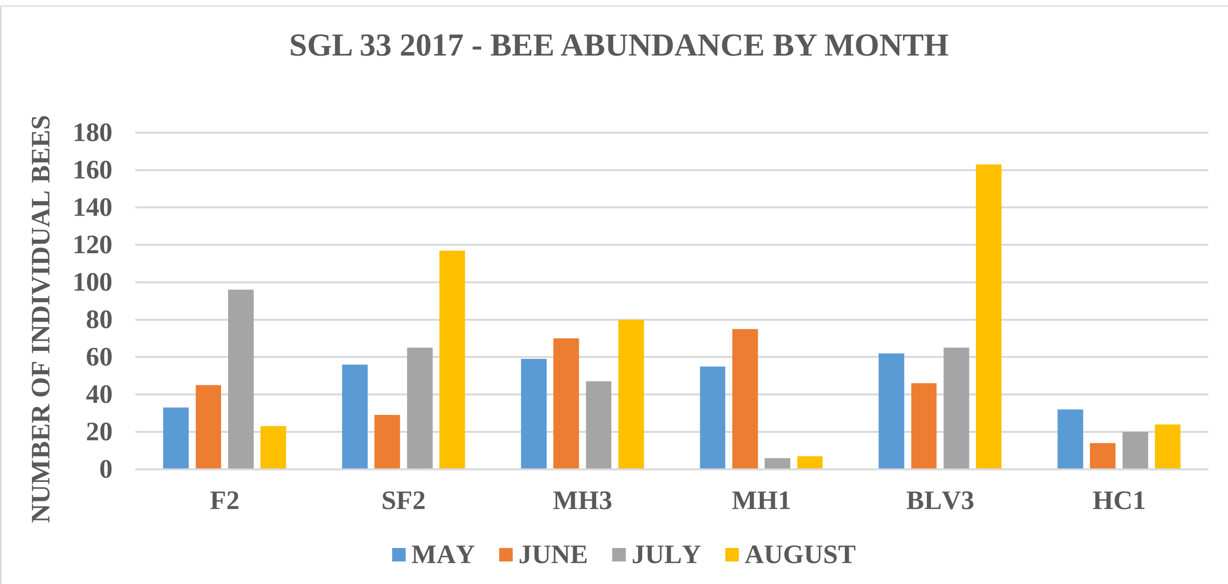

Figure P-7. Bee abundance per plot by month at SGL 33 for 2017.

Table P-6. Bee taxa richness per plot by month at SGL 33 for 2017.

SGL33 2017 - BEE RICHNESS PER PLOT BY MONTH (NUMBER OF BEE TAXA)						
	F2	SF2	MH3	MH1	BLV3	HC1
MAY	14	**21**	23	21	**25**	**18**
JUNE	**23**	13	**28**	**35**	17	9
JULY	7	17	22	4	11	12
AUGUST	15	15	24	5	18	14

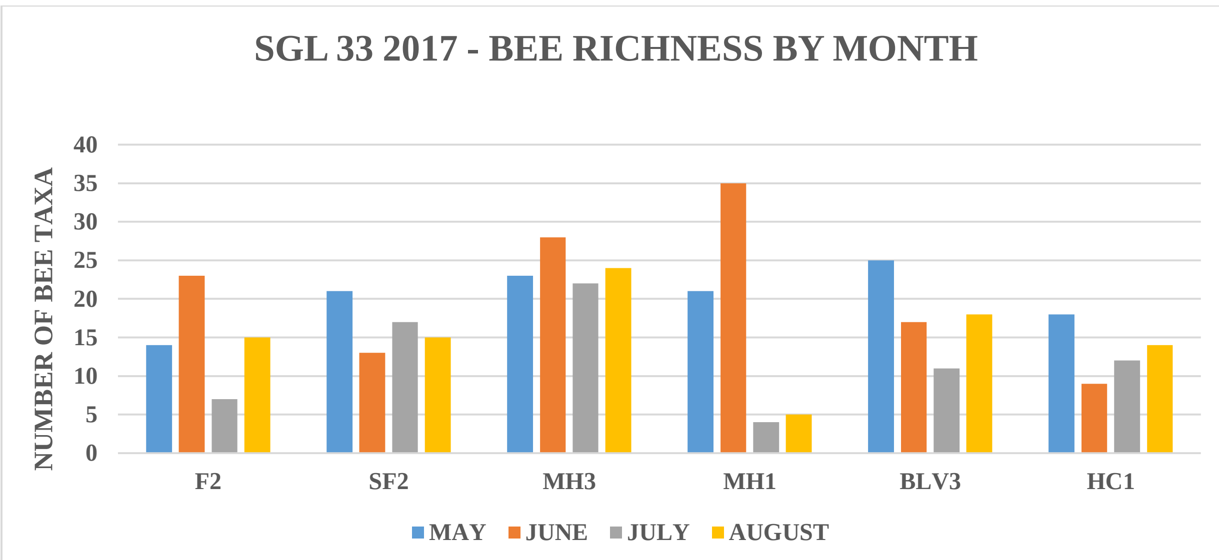

Figure P-8. Bee taxa richness per plot by month at SGL 33 for 2017.

Table P-7. Bee abundance per plot at SGL 33 for 2016 and 2017.

SGL 33 ABUNDANCE OF BEES (NUMBER OF INDIVIDUALS)

Plot	2016	2017
F2	132	197
SF2	188	266
MH3	235	256
MH1	160	143
BLV3	316	336
HC1	25	90

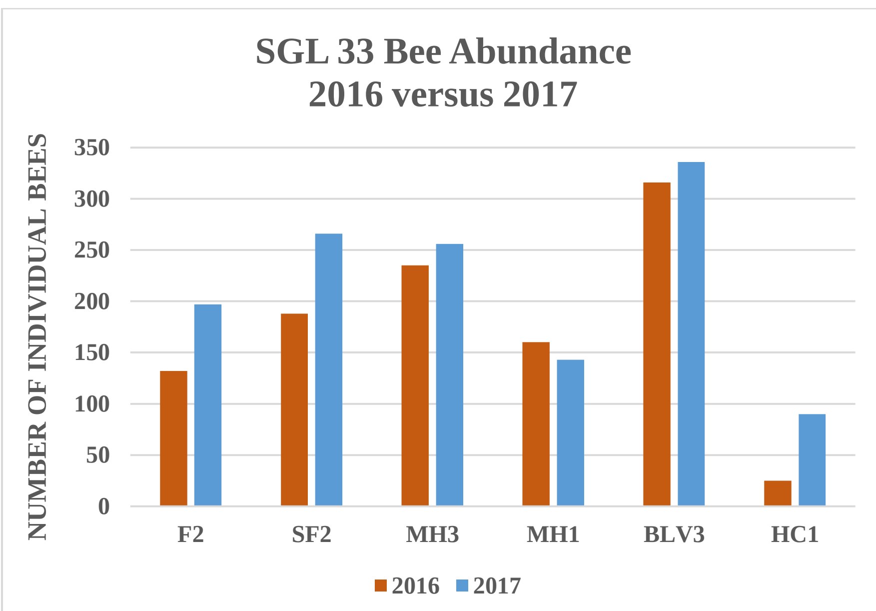

Figure P-9. Bee abundance per plot at SGL 33 for 2016 and 2017.

Table P-8. Bee taxa richness per plot at SGL 33 for 2016 and for 2017.

SGL 33 RICHNESS OF BEES (NUMBER OF TAXA)

Plot	2016	2017
F2	34	41
SF2	48	41
MH3	47	63
MH1	43	51
BLV3	66	45
HC1	*13*	*33*

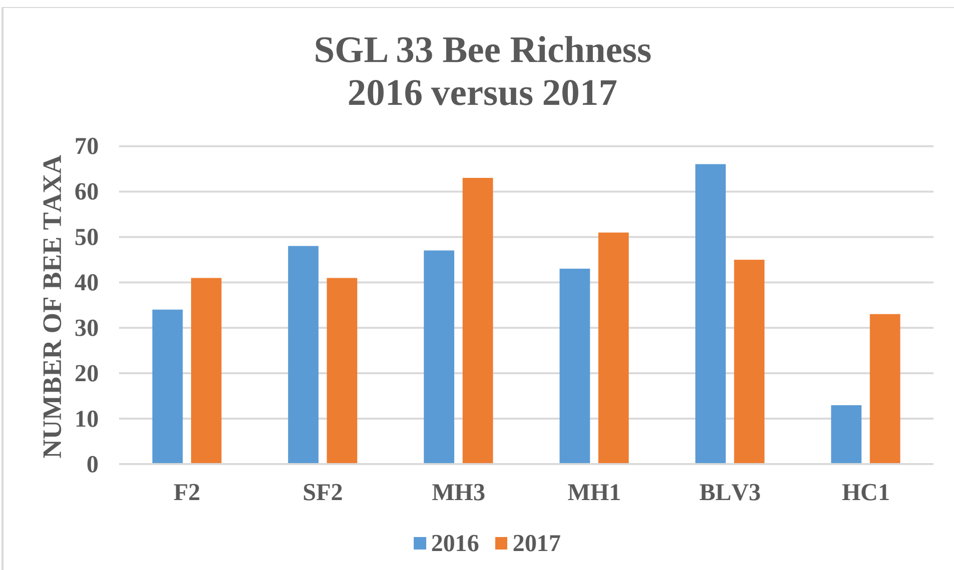

Figure P-10. Bee taxa richness per plot at SGL 33 for 2016 and 2017.

Table P-9. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at SGL 33 for 2016 and 2017.

SGL33 - SHANNON DIVERSITY 2016 v 2017				
	2016 Diversity	2016 Evenness	2017 Diversity	2017 Evenness
F2	2.902	0.830	2.698	0.726
SF2	**3.385**	0.874	2.792	0.752
MH3	3.062	0.795	3.421	0.826
MH1	3.192	0.849	**3.427**	0.872
BLV3	3.060	*0.730*	*2.246*	*0.590*
HC1	*2.435*	**0.949**	3.098	**0.886**

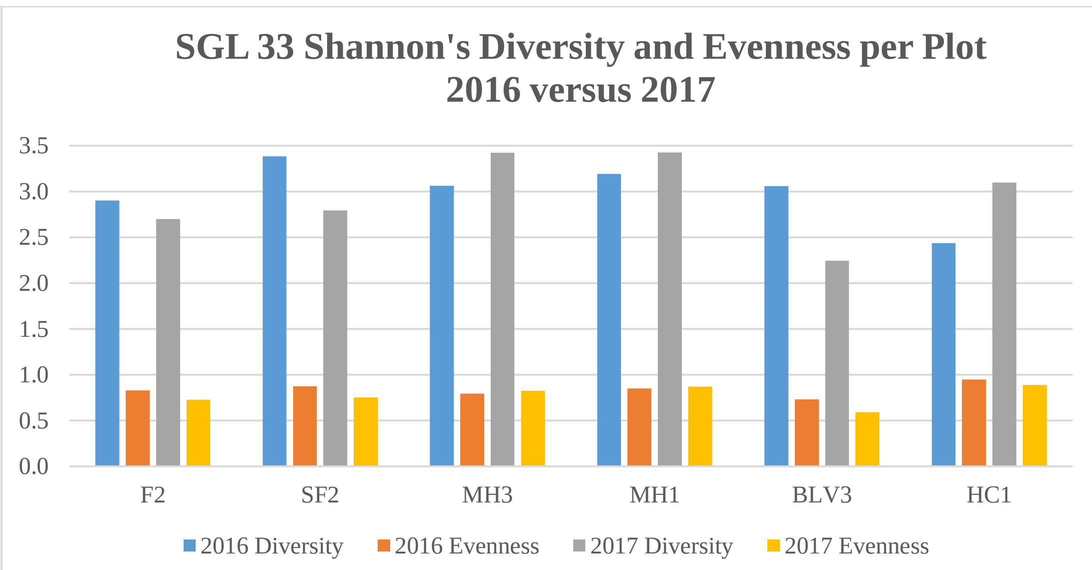

Figure P-11. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at SGL 33 for 2016 and 2017.

Table P-10. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at SGL 33 for 2016 and 2017.

SGL33 - SIMPSON DIVERSITY 2016 v 2017				
	2016 Diversity	2016 Evenness	2017 Diversity	2017 Evenness
F2	0.899	0.292	0.854	0.168
SF2	**0.948**	0.399	0.897	0.238
MH3	0.907	0.229	0.940	0.263
MH1	0.929	0.327	**0.944**	0.352
BLV3	*0.891*	*0.139*	*0.705*	*0.075*
HC1	0.902	**0.788**	0.940	**0.501**

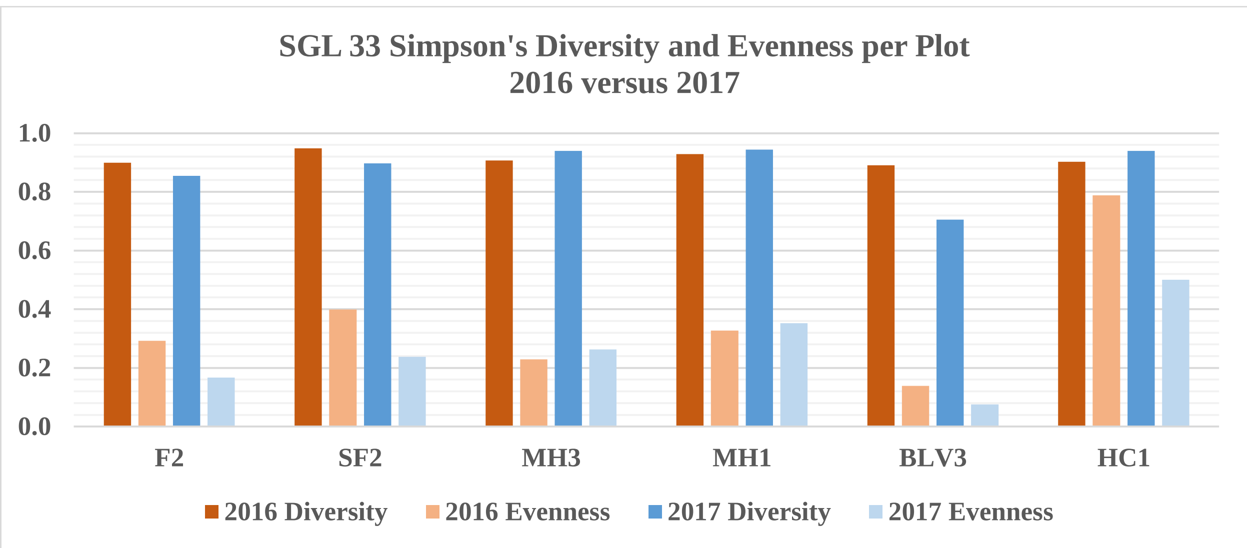

Figure P-12. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at SGL 33 for 2016 and 2017.

Table P-11. Abundance of bees per plot at GLR&D for 2017.

2017 GLR&D BEE ABUNDANCE

Plot	(# Individuals)
F1	62
MH1	121
M1	101
SF2	93
HC2	77

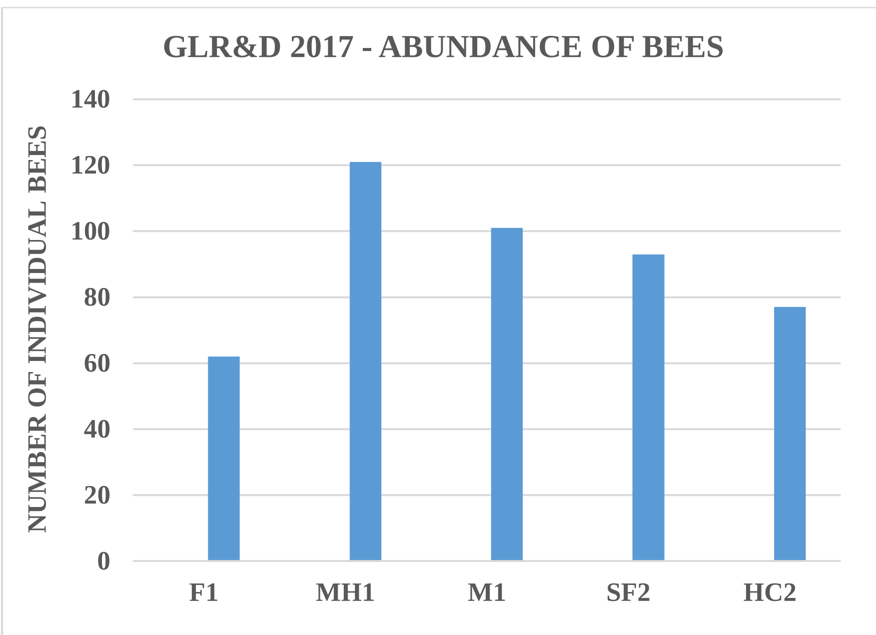

Figure P-13. Abundance of bees per plot at GLR&D for 2017.

Table P-12. Bee taxa richness per plot at GLR&D for 2017.

2017 GLR&D BEE RICHNESS	
Plot	(# of Taxa)
F1	25
MH1	18
M1	22
SF2	20
HC2	*13*

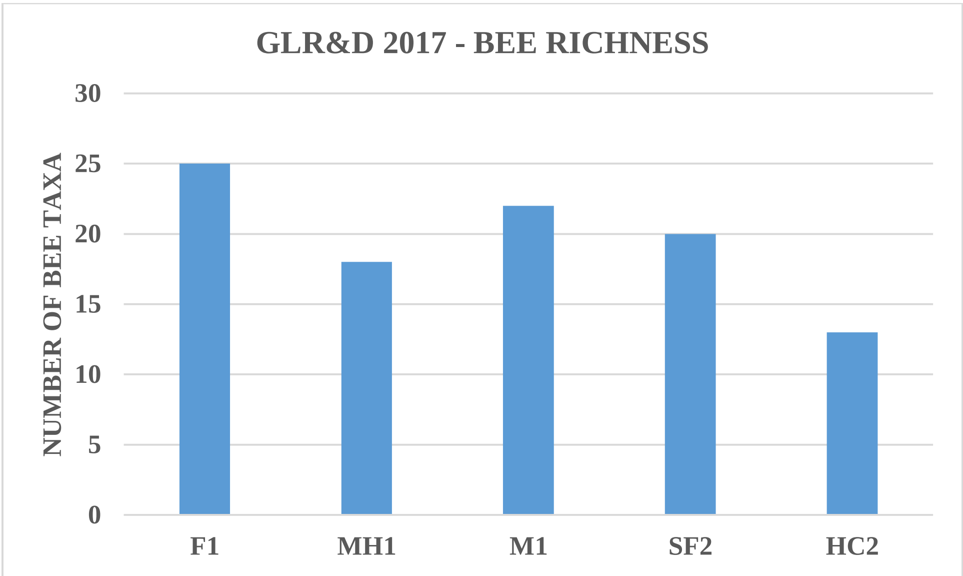

Figure P-14. Bee taxa richness per plot at GLR&D for 2017.

Table P-13. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at GLR&D for 2017.

2017 Green Lane - SHANNON DIVERSITY		
	2017 Diversity	2017 Evenness
F2	**2.607**	**0.810**
MH1	*1.590*	*0.550*
M1	1.940	0.628
SF2	2.127	0.710
HC2	1.643	0.640

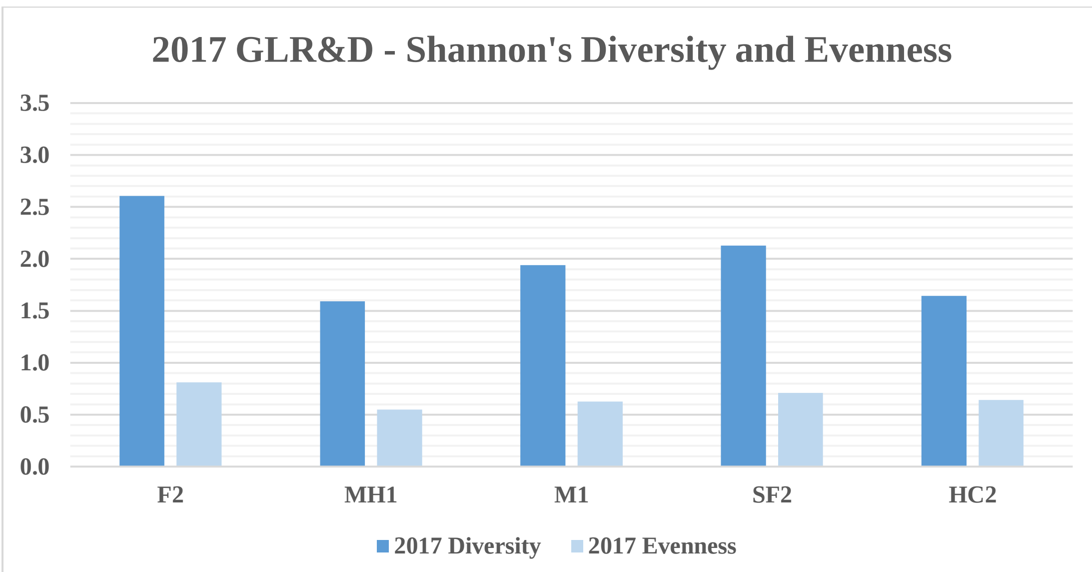

Figure P-15. Shannon's Diversity Index (H) and Evenness (E_H) of bees per plot at GLR&D for 2017.

Table P-14. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at GLR&D for 2017.

2017 Green Lane - SIMPSON DIVERSITY		
	2017 Diversity	2017 Evenness
F2	**0.857**	**0.281**
MH1	*0.619*	*0.146*
M1	0.694	0.148
SF2	0.790	0.239
HC2	0.703	0.259

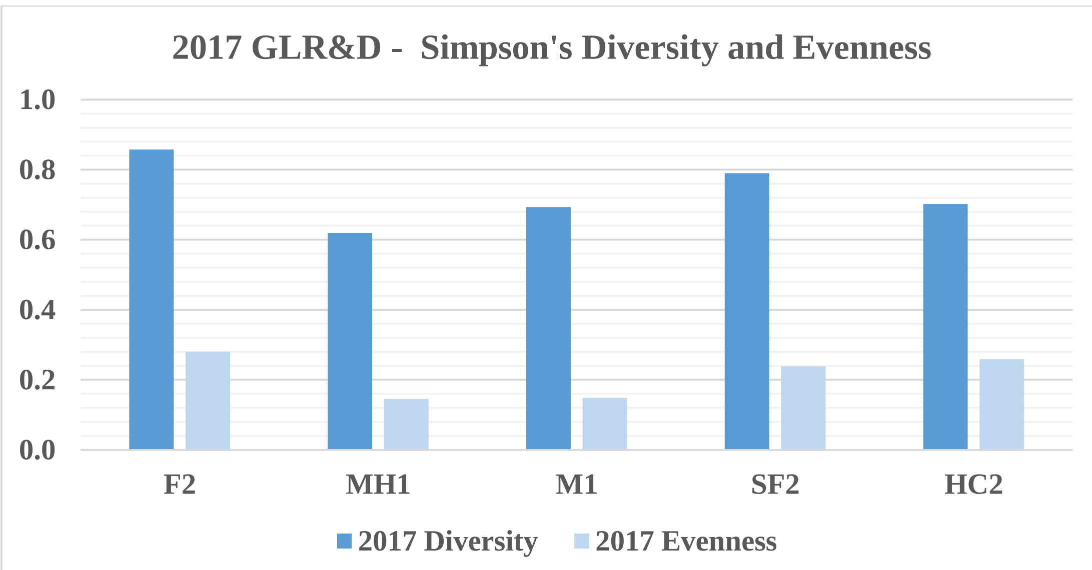

Figure P-16. Simpson's Index of Diversity (1-D) and Evenness (E_D) of bees per plot at GLR&D for 2017.

Table P-15. Bee abundance per plot by month at GLR&D for 2017.

GREEN LANE 2017 - BEE ABUNDANCE PER PLOT BY MONTH (NUMBER OF INDIVIDUAL BEES)					
	F1	**MH1**	**M1**	**SF2**	**HC2**
MAY	17	20	20	27	11
JUNE	11	9	10	21	6
JULY	**34**	**92**	**71**	**45**	**60**

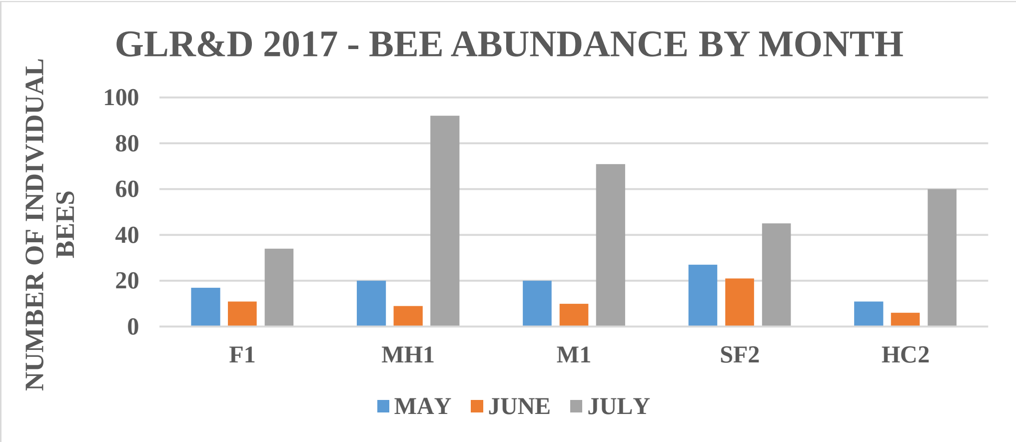

Figure P-17. Bee abundance per plot by month at GLR&D for 2017.

Table P-16. Bee taxa richness per plot by month at GLR&D for 2017.

GREEN LANE 2017 - BEE RICHNESS PER PLOT BY MONTH (NUMBER OF BEE TAXA)					
	F1	MH1	M1	SF2	HC2
MAY	**15**	**12**	**12**	7	5
JUNE	10	5	6	**13**	5
JULY	9	8	11	6	**7**

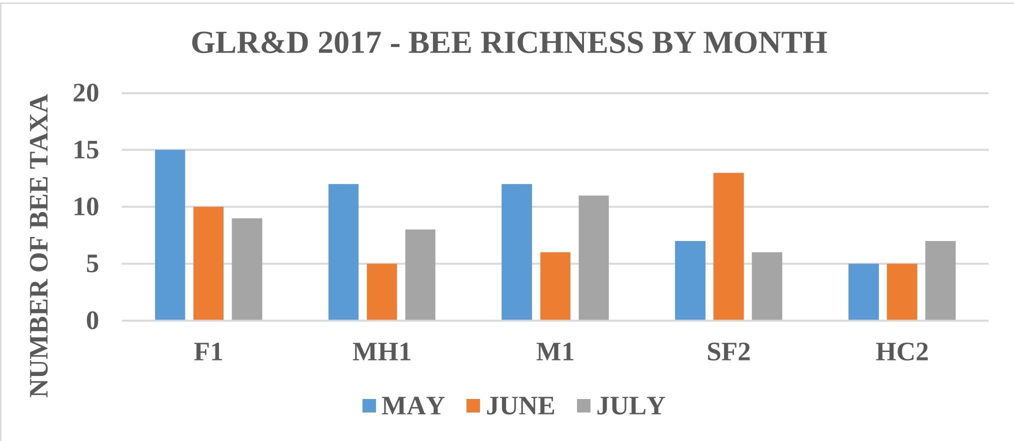

Figure P-18. Bee taxa richness per plot by month at GLR&D for 2017.

Table P-17. Summary of results for bee collections at SGL 33 in 2017.

SGL33 - Bee Survey 2017 - Summary of Results						
	F2	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
HERBICIDES?	YES	YES	YES	YES	YES	NO
LOW OR HIGH VOLUME?	HIGH	ULTRA LOW	ULTRA LOW	ULTRA LOW	LOW	–
WATER OR OIL-BASED?	WATER	OIL	OIL	OIL	OIL	–
SELECTIVE? (mechanical or herbicidal)	NO	YES	YES	YES	YES	YES
Rankings						
ABUNDANCE (# INDIVIDUALS)	4th (197)	2nd (266)	3rd (256)	5th (143)	**1st (336)**	6th (90)
RICHNESS (# TAXA)	4th (41)	4th (41)	**1st (63)**	2nd (51)	3rd (45)	6th (33)
SHANNON'S DIVERSITY INDEX	5th (2.698)	4th (2.792)	2nd (3.421)	**1st (3.427)**	6th (2.246)	3rd (3.098)
SHANNON'S EVENNESS	5th (0.7264)	4th (0.7519)	3rd (0.8257)	2nd (0.8716)	6th (0.5900)	**1st (0.8861)**
SIMPSON'S INDEX OF DIVERSITY	5th (0.8544)	4th (0.8973)	2nd (0.9397)	**1st (0.9443)**	6th (0.7054)	3rd (0.9395)
SIMPSON'S EVENNESS	5th (0.1675)	4th (0.2376)	3rd (0.2632)	2nd (0.3520)	6th (0.0754)	**1st (0.5009)**

Table P-18. Specialist bee species collected at SGL 33 in 2017.

Specialist Bees Collected at SGL 33 - 2017

Plant	**Bee**	**Status**	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
Aster family (e.g. goldenrods)	*Andrena hirticincta*		X	X	X			
	Andrena nubecula	patchy	X					
	Colletes simulans		X	X	X			
	Megachile pugnata	uncommon			X			
	Melissodes illatus/subillatus					X		
Heather family (e.g. blueberries)	*Andrena carolina*	patchy		X	X		X	X
	Andrena vicina			X		X	X	
	Osmia atriventris		X	X		X	X	X
Loosestrife	*Macropis ciliata*	rare	X					

Table P-19. Summary of results for bee collections at GLR&D in 2017.

Green Lane - Bee Survey 2017 - Summary of Results					
	Hydraulic Foliar	Mow w/ Treatment	Mow	Stem Foliar	Hand Cut
HERBICIDES?	YES	YES	NO	YES	NO
LOW OR HIGH VOLUME?	HIGH	LOW	–	ULTRA LOW	–
WATER OR OIL-BASED?	WATER	WATER	–	OIL	–
SELECTIVE? (mechanical or herbicidal)	NO	YES	NO	YES	YES
Rankings					
ABUNDANCE (# INDIVIDUALS)	5th (62)	**1st (121)**	2nd (101)	3rd (93)	4th (77)
RICHNESS (# TAXA)	**1st (25)**	4th (18)	2nd (22)	3rd (20)	5th (13)
SHANNON'S DIVERSITY INDEX	**1st (2.607)**	5th (1.590)	3rd (1.940)	2nd (2.127)	4th (1.643)
SHANNON'S EVENNESS	**1st (0.8098)**	5th (0.5501)	4th (0.6275)	2nd (0.7100)	3rd (0.6404)
SIMPSON'S INDEX OF DIVERSITY	**1st (0.8574)**	5th (0.6191)	4th (0.6935)	2nd (0.7904)	3rd (0.7026)
SIMPSON'S EVENNESS	**1st (0.2806)**	5th (0.1458)	4th (0.1483)	3rd (0.2386)	2nd (0.2587)

Table P-20. Specialist bee species collected at GLR&D in 2017.

Specialist Bees Collected at Green Lane - 2017

Plant	Bee	Status	F1	MH1	M1	SF2	HC2
Heather family (e.g. blueberries)	*Osmia atriventris*		X				
Dwarf-dandelion	*Andrena krigiana*				X		
Pickerelweed	*Melissodes apicatus*					X	

FUTURE CONSIDERATIONS

The use of integrated vegetation management (IVM) to achieve an objective of compatible plant persistence under electrical transmission rights-of-way has been the foundation of this research project for 65 years. To determine wildlife response to IVM and its use of mechanical and/or herbicide approaches, some consistency in maintenance is needed at the study sites. With that in mind, we urge land managers at SGL 33 to maintain M4 as mowing; HC1 as hand-cutting, and LVB3 as low volume basal; ULVF1 as ultra-low volume foliar; and HVF1 as high volume foliar. A review of Table I-1 and Appendix A will indicate some inconsistency in vegetation maintenance over the years. Thus, it is difficult to recommend a fine-tuned treatment that is best for species sensitive to management approaches such as Hymenopteran pollinators.

Regardless of width, border zones are important for breeding birds using ROW at our study areas. Great effort should be used to maintain borders (even 10-foot borders) and implement the wire-border zone method on all electrical ROW as a best practice. This approach is important for all terrestrial vertebrates as evidence by our current research on birds and past work on amphibians/reptiles and small mammals.

The immediate-adjacent ROW managed by PPL makes our research conclusions difficult at the GLR&D study site. We note high level of disturbance both on the PPL ROW and in the landscape surrounding the GLR&D study site, in general. It does appear, however, that wildlife use of the ROW is compatible with water-based delivery of herbicides at this site.

Hymenopteran pollinators seem to be compatible with highly-selective and ultra-low volume applications of herbicides. For the 2nd year in a row, Hymenopteran species richness and abundance is highest on treatments with herbicide (e.g., LVB) use. Treatment sites MH1 (treated as ULVF in 2016), MH3 (treated as ULVF in 2016), and LVB have the highest Hymenopteran species richness and/or abundance. In addition, specialist and/or uncommonly-encountered species of bees were found on all treatment units.

Finally, this research has begun to document the subtle shifts in species assemblages throughout a multi-year vegetation management cycle on ROW. For example, bee community composition was more dominated by bumble bees in the year immediate after ROW treatment. In addition, bird abundance and nesting success on the ROW dropped in the year immediately after treatment but we expect it to rebound as the vegetation community undergoes succession. This decrease in abundance and nesting success also may be due to the reduction in border zone width in 2016.

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Appendix A. Most recent vegetation treatment applications and sample treatment unit photographs at State Game Lands (SGL) 33 and Green Lane Research and Development (GLR&D) right-of-way sites.

SGL 33 Legacy Treatment Acronym	**SGL 33 Legacy Treatment Unit**	**SGL 33 2016 Application**	**SGL 33 Herbicide Gallons Used-wire zone**	**SGL 33 Total Man Hours**	**SGL 33 Bar Oil**	**SGL 33 Gas**	**SGL 33 Crew**
HC1	Hand Cut	Hand Cut	0	70 hours	1.5 gallon	3.5	5
BLV3 (BHV1)	Basal Low Volume	Low Volume Basal	2 gallon 7 pints	4 hours	0	0	3
MH1	Mow plus Herbicide	Ultra-Low Volume Foliar	2 quarts	40 minutes	0	0	2
BLV1	Basal Low Volume	Low Volume Basal	2.5 gallons	3 hours	0	0	3
F1	Foliage Spray	Ultra-Low Volume Foliar	3 gallon 5 pints	52 minutes	0	0	2
M1	Mowing	Ultra-Low Volume Foliar	2 quarts	90 minutes	0	0	3
BLV4 (BHV2)	Basal Low Volume	Low Volume Basal	4 gallon 5 pints	90 minutes	0	0	3
HC2	Hand Cut	Hand Cut	0	25 hours	1 quart	1	5
SF1	Stem Foliar	Ultra-Low Volume Foliar	5 pints	30 minutes	0	0	1
M2	Mowing	Ultra-Low Volume Foliar	3 pints	20 minutes	0	0	1
BLV2	Basal Low Volume	Low Volume Basal	4 gallons	6 hours 4 minutes	0	0	3
MH3 (MH2)	Mow with Treatment	Ultra-Low Volume Foliar	2 gallon	2 hours 10 minutes	0	0	2
SF2	Stem Foliar	High Volume Foliar	25	1 hour 5 minutes	0	0	2
F2	Foliage Spray	High Volume Foliar	75 gallons	4 hours	0	0	2
M4 (M3)	Mowing	Mowing	0	6 hours	0	N/A	2

GLR&D Legacy Treatment Acronym	GLR&D Legacy Treatment Unit	GLR&D 2014 Application	GLR&D Herbicide/treatment used - wire zone
M1, M2	Mowing	Mowing (M)	Mow all woody vegetation.
MH1, MH2	Mowing plus herbicide	Mowing cut stubble (MCS)	Mow all woody vegetation and apply an ultra-low volume broadcast application of 14oz Viewpoint + 7oz Milestone in 15 gallons water applied at 15 gallons per acre.
SF1, SF2	Stem foliar	Ultra-low volume foliar (ULVF)	Spray all trees and tall shrubs to the point of runoff and their stem with Arsenal 4oz/100gal + Escort XP 1oz/100gal + Milestone 5oz/100gal + Garlon 3A 2qts/100gal+ Clean Cut ½% + 41-A drift control 6oz/100 gal.
F1, F2	Foliage spray	High volume foliar (HVF)	Spray all trees and tall shrubs to coverage with Rodeo 7% + Arsenal 1% + Escort XP 4oz/100gal in Thinvert.
HC1, HC2	Hand cut	Hand cut (HC)	Clear cut all woody vegetation in the wire zone and 15ft outside.

SGL 33, Legacy site: F2 (Foliage spray); New treatment term: high volume foliar (HVF); HVF 2016.

SGL 33, Legacy site SF2 (stem foliar); New treatment term: ultra-low volume foliar (ULVF); HVF 2016.

SGL 33, Legacy site MH3 (mowing plus herbicide); New treatment term: mowing cut stubble (MCS); ULVF 2016. Photo: D. Roberts (2016).

SGL 33, Legacy site BLV3 (basal low volume); New treatment term: low volume basal (LVB); LVB 2016. Photo: D. Roberts (2016).

SGL 33, Legacy site HC1 (hand cut); New treatment term: hand cut (HC); HC 2016. Photo: D. Roberts (2016).

GLR&D, Legacy site F1 (foliage spray); New treatment term: high volume foliar (HVF); HVF 2014. Photo: H. Stout (2017).

GLR&D, Legacy site MH1 (mowing plus herbicide); New treatment term: mowing cut stubble (MCS); MCS 2014. Photo: H. Stout (2017).

GLR&D, Legacy site M1 (mowing); New treatment term: mowing (M); M 2014.
Photo: H. Stout (2017).

GLR&D, Legacy site SF2 (stem foliar); New treatment term: ultra-low volume foliar (ULVF); ULVF 2014. Photo: H. Stout (2017).

GLR&D, Legacy site HC2 (hand cut); New treatment term: hand cut (HC); HC 2014.
Photo: H. Stout (2017).

Appendix B. Outreach efforts related to rights-of-way research and demonstration sites at State Game Lands 33 and Green Lane Research and Development area 2016-2018.

Speaking engagements/poster presentations:

State Game Lands 33 Vegetation Management Project
Pennsylvania Roadside Vegetation Management Conference
August 2016, State College, PA

The right-of-way is buzzing: managing pollinator habitats
Southern Gas Association,
February 2017, Tampa, FL

Wildlife use (pollinators and birds) of rights-of-way in Pennsylvania
Pennsylvania Private Forest Landowners Conference
March 2017, Blair County Convention Center, Altoona, PA

Use of electric rights-of-way by native bees
Appalachian Vegetation Management Association
March 2017, Roanoke, WV

Initial findings of pollinator use of rights-of-way in Pennsylvania: report
Pacific Gas and Electric, Sacramento Municipal Utility District
May 2017, Sacramento, CA

*The effect of vegetation management approaches on electric transmission right-of-ways on bees**
Trees and Utilities National Conference
September 2017, Kansas City, MO

*Also presented at:

> Entomological Society of America Annual Meeting
> November 2017, Denver, CO
>
> Wildlife Habitat Council Annual Conference
> November 2017, Baltimore, MD

Can utility rights-of-way help native bees?
Faculty seminar, Penn State Altoona
January 2018, Altoona, PA

Bird use and nesting success on electric rights-of-way in Pennsylvania
Pennsylvania Chapter of the Wildlife Society Conference
March 2018, State College, PA

Response of bee community to vegetation management approaches on electric transmission rights-of-way
Penn State Graduate Program in Ecology
April 2018, University Park, PA

Retrofitting GIS to enhance the study of rights-of-way ecology
Pennsylvania Annual Geographic Information (GIS) Conference
May 2018, University Park, PA

Pollinator Habitat Workshop, participant
Electric Power Research Institute (EPRI), Edison Electric Institute, and the Energy Resources Center at the University of Illinois-Chicago (UIC) Rights-of-Way as Habitat Working Group
May 2018, Washington DC

Written communications

Update on SGL 33 and Green Lane Research (Kristin Wild, Asplundh)
September 2016, Utility Arborist Newsline, pp. 22-23
http://www.asplundh.com/wp-content/uploads/2017/02/Gamelands33_JanFeb-2017_UAA-Newsline.pdf

The power of partnerships: public-private alliances in utility arboriculture research
(J. Eric Smith) November 2017, Utility Arborist Newsline, pp. 1-4.

Use of ROWs by bees: initial research summary from Pennsylvania (C. Mahan/K.Wild)
January 2018, Utility Arborist Newsline, pp. 21-22.

Russo, L., H. Stout, D. Roberts, B. Ross, and C. Mahan. 2018. Powerline cut management and flower-visiting insects: How vegetation management can promote pollinator diversity, Submitted to *J. Pollinator Ecology*.

Bonta, M. 2018. Right of way habitat lies beneath the lines. *Pennsylvania Game News*, Harrisburg, PA, pp. 61-63.

Web features

Utility rights-of-way research at Penn State
Latest research findings: plant and animal response to rights-of-way treatments
https://sites.psu.edu/transmissionlineecology/

Maintaining the right-of-way the right way (Terry Boyd, Penn State Altoona)
Penn State News/Penn State Research and Teaching
https://altoona.psu.edu/feature/maintaining-right-way-right-way

Skulls and bees lead to research opportunities for undergrad (Terry Boyd, Penn State Altoona)
Penn State News/Penn State Research and Teaching
https://news.psu.edu/story/444613/2017/01/11/skulls-and-bees-lead-research-opportunities-undergrad

Right-of-way science (M. Bonta, naturalist/writer). June 2018
https://marciabonta.wordpress.com/2018/06/01/right-of-way-science/

Site visits

August 2016, Hosted a 35 participant tour of SGL 33 in conjunction with Pennsylvania Roadside Maintenance Conference, Penn State Extension/Pennsylvania Department of Transportation.

June 2017, Hosted a 39 participant tour of SGL 33 to demonstrate research partnership and initial findings on the effects of right-of-way management on bees (participants included PA Game Commission, Asplundh, First Energy, PECO, Ohio State, Penn State).

Academic/scholarly partnerships

Center for Pollinator Research at Penn State

Frost Entomological Museum, University Park, PA

U.S. Geological Survey (USGS) Bee Inventory and Monitoring Database (Sam Droege),

Pennsylvania Bee Atlas project

Appendix C. Latin name and common name of potential Lepidopteran species present on State Game Lands 33 Rights-of-Way Research and Demonstration Area based upon the documentation of their larval host plant species, 2016.

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
1. *Acleris chalybeana*	Lesser maple leafroller moth	*Acer rubrum; Quercus rubra*	*Red maple, red oak*
2. *Acleris keiferi*	No common name	*Rubus sp*	*Blackberry*
3. *Acrobasis comptoniella*	Sweetfern leaf casebearer	*Comptonia peregrina*	*Sweet fern*
4. *Acrocercops sp*	No common name	*Solidago sp*	*Goldenrod*
5. *Acronicta americana*	American dagger moth	*Acer rubrum*	*Red maple*
6. *Acronicta haesitata*	Hesitant dagger moth	*Quercus rubra*	*Red oak*
7. *Acronicta hamamelis*	Witch hazel dagger moth	*Hamamelis virginiana*	*Witch hazel*
8. *Acronicta lanceolaria*	Lanceolate dagger moth	*Comptonia peregrina*	*Sweet fern*
9. *Acronicta noctivaga*	Night-wandering dagger moth	*Quercus rubra; Apocynum sp.*	*Red oak, dogbane*
10. *Actias luna*	Luna moth	*Quercus rubra*	*Red oak*
11. *Agonopterix clemensella*	No common name	*Sanicula canadensis*	*Snake root*
12. *Agonopterix oregonensis*	No common name	*Sanicula canadensis*	*Snake root*
13. *Albuna fraxini*	Virginia creeper clearwing	*Parthenocissus quinquefolia*	*Virginia creeper*
14. *Amorbia humerosana*	White-lined leafroller	*Viburnum sp., Solidago sp.*	*Viburnums, Goldenrod*
15. *Amphion floridensis*	Nessus sphinx moth	*Parthenocissus quinquefolia*	*Virginia creeper*
16. *Amphipyra pyramidoides*	Copper underwing	*Parthenocissus quinquefolia*	*Virginia creeper*
17. *Amphipyra tragopoginis*	Mouse moth	*Apocynum sp.*	*Dogbane*
18. *Anagrapha falcifera*	Celery looper	*Viburnum sp.*	*Viburnums*
19. *Ancylis comptana*	Strawberry leafroller	*Solidago sp.*	*Goldenrod*
20. *Anisota senatoria*	Orangestriped oakworm	*Quercus rubra*	*Red oak*
21. *Anterastria teratophora*	Grey marvel moth	*Mentha sp.; Monarda*	*Mint**, *Bee balm*
22. *Antheraea polyphemus*	Polyphemus moth	*Prunus serotina*	*Black cherry*
23. *Apatelodes torrefacta*	Spotted apatelodes	*Prunus serotina*	*Black cherry*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
24. *Archips argyrospila*	Fruit-tree leafroller moth	*Comptonia peregrina*	*Sweet fern*
25. *Archips cerasivorana*	Ugly-nest caterpillar Moth	*Prunus serotina*	*Black cherry*
26. *Archips crataegana*	Brown oak tortrix	*Hamamelis virginiana*	*Witch hazel*
27. *Archips fuscocupreanus*	Exotic leafroller moth	*Prunus serotina*	*Black cherry*
28. *Archips purpurana*	Omnivorous leafroller moth	*Solidago sp.*	*Goldenrod*
29. *Arctia caja*	Great/Garden tiger moth	*Pteridium aquilinum*	*Eastern bracken fern*
30. *Argyrotaenia citrana*	Orange tortrix	*Rubus sp.*	*Blackberry*
31. *Argyrotaenia franciscana*	Apple skinworm	*Solidago sp., Rubus sp.*	*Goldenrod, blackberry*
32. *Artace cribraria*	No common name	*Prunus serotina*	*Black cherry*
33. *Autographa bimaculata*	Twin gold spot	*Urtica dioica*	*Stinging nettle*
34. *Autographa mappa*	Wavy chestnut Y	*Urtica dioica*	*Stinging nettle*
35. *Autographa precationis*	Common looper moth	*Urtica dioica*	*Stinging nettle*
36. *Automeris io*	Io moth	*Prunus serotina, Acer rubrum, Quercus rubra, Comptonia peregrina*	*Black cherry, red maple, red oak, sweet fern*
37. *Automeris louisiana*	No common name	*Prunus serotina*	*Black cherry*
38. *Basicladus celibatus*	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*
39. *Basilarchia arthemis*	Red-spotted purple	*Prunus serotina*	*Black cherry*
40. *Bucculatrix ainsliella*	Oak leaf skeletonizer	*Quercus rubra*	*Red oak*
41. *Callopistria cordata*	No common name	*Pteridium aquilinum*	*Sweet fern*
42. *Callosamia angulifera*	Tuliptree silkmoth	*Prunus serotina, Liriodendron tulipifera*	*Black cherry, Tulip tree*
43. *Callosamia promethea*	Promethea silkmoth	*Berberis vulgaris, Prunus serotina, spicebush*	*Barberry*, Black cherry, Lindera benzoin*
44. *Caloptilia aceriella*	No common name	*Acer rubrum*	*Red maple*
45. *Caloptilia asplenifoliatella*	No common name	*Comptonia peregrina*	*Sweet fern*
46. *Caloptilia bimaculatella*	No common name	*Acer rubrum*	*Red maple*
47. *Caloptilia burgessiella*	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*
48. *Caloptilia serotinella*	Cherry leafroller	*Prunus serotina*	*Black cherry*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
49. Caloptilia speciosella	No common name	*Acer rubrum*	*Red maple*
50. Caloptilia superbifrontella	No common name	*Hamamelis virginiana*	*Witch hazel*
51. Caloptilia umbratella	No common name	*Acer rubrum*	*Red maple*
52. Caloptilia vacciniella	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*
53. Cameraria aceriella	Maple leafblotch miner	*Hamamelis virginiana, Acer rubrum*	*Witch hazel, red maple*
54. Cameraria bethunella	No common name	*Quercus rubra*	*Red oak*
55. Cameraria hamadryadella	Solitary oak leaf miner	*Quercus rubra*	*Red oak*
56. Cameraria hamameliella	No common name	*Hamamelis virginiana*	*Witch hazel*
57. Cameraria saccharella	No common name	*Acer rubrum*	*Red maple*
58. Cameraria ulmella	No common name	*Quercus rubra*	*Red oak*
59. Catastega aceriella	Maple trumpet skeletonizer moth	*Acer rubrum, Quercus rubra*	*Red maple, red oak*
60. Catocala amica	Girlfriend underwing	*Quercus rubra*	*Red oak*
61. Catocala antinympha	Sweetfern underwing	*Comptonia peregrina*	*Sweet fern*
62. Catocala coelebs	Old maid	*Comptonia peregrina*	*Sweet fern*
63. Catocala lineella	Lineella underwing	*Quercus rubra*	*Red oak*
64. Celastrina argiolus	Holly blue	*Vaccinium corymbosum, Lonicera sp., Prunus serotina*	*Lowbush blueberry, bush honeysuckle*, black cherry*
65. Cerastis tenebrifera	Reddish speckled dart	*Prunus virginiana*	*Choke cherry*
66. Ceratomia undulosa	Waved sphinx	*Quercus rubra*	*Red oak*
67. Charidryas gorgone	No common name	*Lysimachia quadrifolia*	*Yellow whorled loosestrife*
68. Charidryas palla	Northern checkerspot	*Solidago sp.*	*Goldenrod*
69. Chionodes sp. (species group)	No common name	*Solidago sp.*	*Goldenrod*
70. Choristoneura fractivittana	Broken-banded leafroller	*Acer rubrum, Quercus rubra*	*Red maple, red oak*
71. Choristoneura parallela	Parallel-banded leafroller	*Acer rubrum*	*Red maple*
72. Choristoneura rosaceana	Rosaceous leafroller	*Rubus sp.*	*Blackberry*
73. Clepsis persicana	White triangle tortrix	*Solidago sp.*	*Goldenrod*
74. Colocasia flavicornis	Yellowhorn	*Acer rubrum*	*Red maple*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
75. Condica videns	White-dotted groundling moth	*Solidago sp.*	*Goldenrod*
76. Cremastobombycia solidaginis	No common name	*Solidago sp.*	*Godenrod*
77. Cryptocala acadiensis	No common name	*Apocynum sp.*	*Dogbane*
78. Ctenoplusia oxygramma	Sharp stigma looper	*Solidago sp.*	*Goldenrod*
79. Cucullia convexipennis	Brown-hooded owlet	*Solidago sp.*	*Goldenrod*
80. Cucullia florea	No common name	*Solidago sp.*	*Goldenrod*
81. Cycnia oregonensis	No common name	*Apocynum sp.*	*Dogbane*
82. Cycnia tenera	Dogbane tiger moth	*Apocynum sp.*	*Dogbane*
83. Cydia latiferreana	Filbertworm moth	*Quercus rubra*	*Red oak*
84. *Danaus plexippus*	Monarch butterfly	*Asclepias sp.*	*Milkweed*
85. Darapsa choerilus	Azalea sphinx	*Parthenocissus quinquefolia, Rhododendron canadense*	*Virginia creeper, native azalea*
86. Darapsa myron	Virginia creeper sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
87. Datana contracta	No common name	*Hamamelis virginiana*	*Witch hazel*
88. Deidamia inscriptum	Lettered sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
89. Diachrysia aereoides	Lined copper looper	*Solidago sp.*	*Goldenrod*
90. Diarsia jucunda	Smaller pinkish dart	*Vaccinium sp., Prunus sp.*	*Blueberry, cherry*
91. Dichomeris bilobella	No common name	*Solidago sp.*	*Goldenrod*
92. Dichomeris leuconotella	No common name	*Solidago sp.*	*Goldenrod*
93. Dolba hyloeus	Pawpaw sphinx	*Comptonia peregrina*	*Sweet fern*
94. Dryocampa rubicunda	Rosy maple moth	*Acer rubrum*	*Red maple*
95. Eacles imperialis	Imperial moth	*Prunus serotina*	*Black cherry*
96. Egira alternans	No common name	*Quercus sp.*	*Oak*
97. Endothenia hebesana	Verbena bud moth	*Solidago sp.*	*Goldenrod*
98. Enyo lugubris	Mournful sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
99. Epiblema desertana	No common name	*Solidago sp.*	*Goldenrod*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
100. Epiblema scudderiana	No common name	*Solidago sp.*	*Goldenrod*
101. Epidemia helloides	Purplish copper	*Rumex acetosella, Polygonum pensylvanicum*	*Common sheep sorrel*, Pennsylvania smartweed*
102. Episimus argutana	No common name	*Solidago sp.*	*Goldenrod*
103. Episimus tyrius	Maple leaftier moth	*Acer rubrum*	*Red maple*
104. Euagrotis illapsa	Snowy dart	*Taxacum sp.*, grasses*	*Dandilion**
105. Eucirroedia pampina	Scalloped sallow	*Prunus serotina*	*Black cherry*
106. Eucosma derelicta	No common name	*Solidago sp.*	*Goldenrod*
107. Eucosma mandana	No common name	*Solidago sp.*	*Goldenrod*
108. Eueretagrotis perattentus	Two-Spot dart	*Pteridium aqilinum*	*Eastern brackenfern*
109. Eulithis diversilineata	Lesser grapevine looper	*Parthenocissus quinquefolia, Vitis sp.*	*Virginia creeper, grape*
110. Eulithis gracilineata	Greater grapevine looper	*Parthenocissus quinquefolia, Vitis sp.*	*Virginia creeper, grape*
111. Eumorpha achemon	Achemon sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
112. Eumorpha pandorus	Pandora sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
113. Eumorpha satellitia	Satellite sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
114. Euphydryas phaeton	Baltimore checkerspot	*Chelone glabra, Plantago lanceolata*	*White turtle head, Plantain**
115. Euplexia benesimilis	No common name	*Pteridium aquilinum*	*Eastern brackenfern*
116. Eupsilia fringata	No common name	*Solidago sp.*	*Goldenrod*
117. Eupsilia tristigmata	No common name	*Prunus serotina*	*Black cherry*
118. Eurois astricta	No common name	*Prunus serotina*	*Black cherry*
119. Eusarca confusaria	Confused eusarca	*Solidago sp.,*	*Goldenrod*
120. Fishia yosemitae	Grey fishia	*Solidago sp.*	*Goldenrod*
121. Gerra sevorsa	No common name	*Parthenocissus quinquefolia*	*Virginia creeper*
122. Gnorimoschema gallaesolidaginis	Goldenrod elliptical-gall moth	*Solidago sp.*	*Goldenrod*
123. Hellinsia homodactylus	No common name	*Solidago sp.*	*Goldenrod*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
124.Helvibotys helvialis	No common name	*Solidago sp.*	*Goldenrod*
125.Hemaris diffinis	Snowberry clearwing	*Apocynum sp.*	*Dogbane*
126.Hemaris thysbe	Hummingbird clearwing	*Prunus sp., Crataegus sp.*	*Cherry, hawthorn*
127.Hemileuca eglanterina	Sheep moth	*Prunus serotina*	*Black cherry*
128.Hemileuca maia	Buck moth	*Prunus serotina, Quercus rubra*	*Black cherry, red oak*
129.Heterocampa biundata	No common name	*Acer rubrum*	*Red maple*
130.Virbia laeta	Joyful holomelina	*Taxacum sp., grasses*	*Dandilion*, grasses*
131.Homochlodes fritillaria	No common name	*Pteridium aquilinum*	*Eastern brackenfern*
132.Homorthodes reliqua	No common name	*Taxacum sp.*	*Dandilion**
133.Hyalophora cecropia	Cecropia moth	*Lonicera sp., Prunus serotina, Parthenocissus quinquefolia, Acer rubrum*	*Honeysuckle*, black cherry, Virginia creeper, red maple*
134.Hydria prunivorata	Ferguson's scallop shell	*Prunus serotina*	*Black cherry*
135.Hyles lineata	White-lined sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
136.Hypercompe scribonia	Giant leopard moth	*Prunus sp., Viola sp.*	*Cherry, violets*
137.Hypomecis buchholzaria	No common name	*Comptonia peregrina*	*Sweet fern*
138.Lacinipolia erecta	No common name	*Taxacum sp.*	*Dandilion**
139.Lacinipolia lustralis	No common name	*Taxacum sp.*	*Dandilion**
140.Leptarctia californiae	No common name	*Pteridium aquilinum*	*Eastern brackenfern*
141.Leuconycta diphteroides	Green owlet	*Solidago sp.*	*Goldenrod*
142.Leuconycta lepidula	Marbled-green jaspidia	*Taxacum sp.*	*Dandilion**
143.Lithophane grotei	No common name	*Prunus serotina*	*Black cherry*
144.Malacosoma americana	Eastern tent caterpillar moth	*Hamamelis virginiana, Prunus serotina*	*Witch hazel, black cherry*
145.Malacosoma disstria	Forest tent caterpillar moth	*Hamamelis virginiana, Prunus serotina*	*Witch hazel, black cherry*
146.Marmara apocynella	No common name	*Apocynum sp.*	*Dogbane*
147.Marmara serotinella	No common name	*Prunus serotina, Rubus sp.*	*Black cherry, blackberry*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
148.Megalopyge crispata	Crinkled flannel moth	*Acer rubrum*	*Red maple*
149.Melanchra assimilis	Black Arches	*Solidago sp., Pteridium aquilinum*	*Goldenrod, Eastern brackenfern*
150.Mniotype ducta	No common name	*Prunus serotina*	*Black cherry*
151.Morrisonia confusa	Confused woodgrain	*Prunus serotina, Acer rubrum, Quercus rubra*	*Black cherry, Red maple, Red oak*
152.Morrisonia latex	Fluid arches	*Prunus serotina, Acer rubrum, Quercus rubra*	*Black cherry, red maple, red oak*
153.Narraga georgiana	No common name	*Solidago sp.*	*Goldenrod*
154.Opostegoides scioterma	No common name	*Ribes uva-crispa*	*Gooseberry*
155.Orthodes cynica	Cynical quaker moth	*Solidago sp.,*	*Goldenrod*
156.Ostrinia ainsliei	No common name	*Solidago sp.*	*Goldenrod*
157.Pandemis lamprosana	Woodgrain leafroller moth	*Hamamelis virginiana, Acer rubrum, Quercus rubra*	*Witch hazel, red maple, red oak*
158.Pandemis pyrusana	Apple pandemis	*Lonicera sp.*, Crataegus sp.*	*Honeysuckle*, Hawthorn*
159.Paonias astylus	Huckleberry sphinx	*Vaccinium corymbosum*	*Lowbush blueberry*
160.Paonias excaecata	Blinded sphinx	*Prunus serotina*	*Black cherry*
161.Paonias myops	Small-eyed sphinx	*Prunus serotina*	*Black cherry*
162.Papaipema duovata	Indigo stem borer moth	*Solidago sp.*	*Goldenrod*
163.Papaipema pterisii	No common name	*Pteridium aquilinum*	*Eastern brackenfern*
164.Papilio glaucus	Eastern tiger swallowtail	*Prunus serotina*	*Black cherry*
165.Papilio troilus	Spicebush swallowtail	*Prunus serotina*	*Black cherry*
166.Paradiarsia littoralis	No common name	*Pteridium aquilinum, Prunus serotina*	*Eastern brackenfern, black cherry*
167.Parallelia bistriaris	Maple looper moth	*Acer rubrum*	*Red maple*
168.Parornix arbitrella	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*
169.Parornix geminatella	Unspotted tentiform leafminer moth	*Prunus serotina*	*Black cherry*
170.Parornix peregrinaella	No common name	*Comptonia peregrina*	*Sweet fern*
171.Parornix preciosella	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*

Appendix C. (continued).

Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
172.Phaneta raracana	No common name	*Solidago sp.*	*Goldenrod*
173.Philedia punctomacularia	No common name	*Pteridium aquilinum*	*Eastern brackenfern*
174.Phlogophora iris	No common name	*Quercus sp.*	*Oak*
175.Phoberia atomaris	Common oak moth	*Quercus rubra*	*Red oak*
176.Phragmatobia assimilans	Large ruby tiger moth	*Apocynum sp.*	*Dogbane*
177.Phyciodes pratensis	Field crescent	*Solidago sp.*	*Goldenrod*
178.Phyllocnistis ampelopsiella	No common name	*Parthenocissus quinquefolia*	*Virginia creeper*
179.Phyllonorycter basistrigella	No common name	*Quercus rubra*	*Red oak*
180.Phyllonorycter comptoniella	No common name	*Comptonia peregrina*	*Sweet fern*
181.Phyllonorycter crataegella	Apple blotch leafminer	*Prunus serotina, Crataegus sp.*	*Black cherry, hawthorn*
182.Phyllonorycter diversella	No common name	*Vaccinium corymbosum*	*Lowbush blueberry*
183.Phyllonorycter fragilella	No common name	*Lonicera sp.*	*Honeysuckle*
184.Phyllonorycter minutella	No common name	*Quercus rubra*	*Red oak*
185.Phyllonorycter propinquinella	Cherry blotch miner moth	*Prunus serotina*	*Black cherry*
186.Phyllonorycter rileyella	No common name	*Quercus rubra*	*Red oak*
187.Phyllonorycter trinotella	No common name	*Acer rubrum*	*Red maple*
188.Platarctia parthenos	St. Lawrence tiger moth	*Apocynum sp.*	*Dogbane*
189.Pleuroprucha insulsaria	Tan wave moth	*Solidago sp., Celastrus sp.*	*Goldenrod, Bittersweet*
190.Proteoteras aesculana	Maple twig borer	*Acer rubrum*	*Red maple*
191.Proteoteras moffatiana	No common name	*Acer rubrum*	*Red maple*
192.Proteoteras willingana	Eastern boxelder twig borer moth	*Acer rubrum*	*Red maple*
193.Proxenus miranda	Miranda moth	*Taxacum sp.*	*Dandilion**
194.Psychomorpha epimenis	Grapevine epimenis	*Parthenocissus quinquefolia, Vitis*	*Virginia creeper, grape*
195.Pyrausta orphisalis	Orange mint moth	*Mentha*	*Mint*
196.Pyrausta subsequalis	No common name	*Prunus serotina*	*Black cherry*
197.Pyrrhia exprimens	Purple-lined sallow	*Apocynum sp.*	*Dogbane*
198.Samia cynthia	Ailanthus silkmoth	*Celastrus sp.. Prunus serotina*	*Bittersweet, black cherry*

Appendix C. (continued).

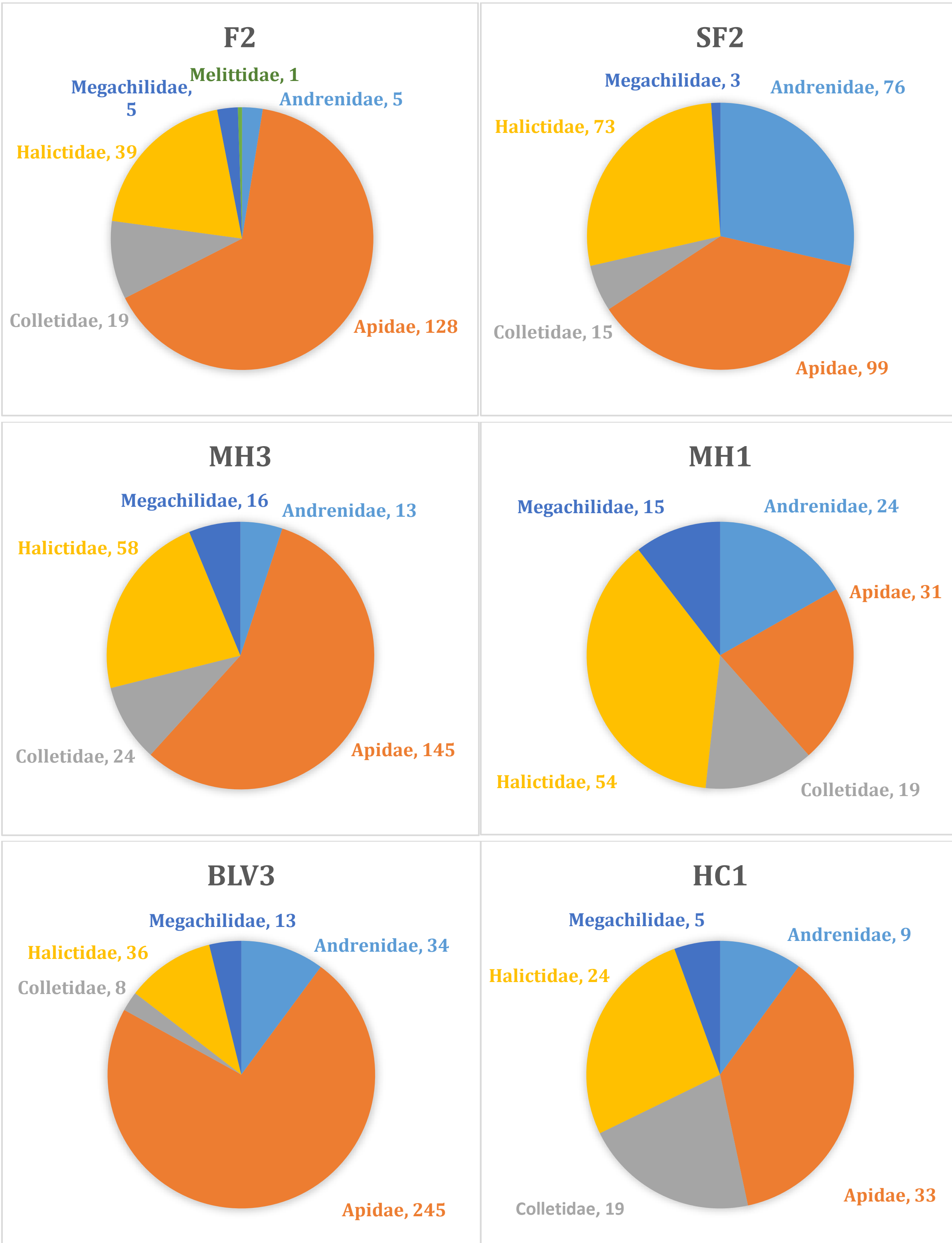
Lepidoptera Latin Name	Lepidopteran Common Name (if available)	Host Plant Species Documented	Host Plant species Common Name
199.Satyrium liparops	Striped Hairstreak	*Vaccinium corymbosum*	*Lowbush blueberry*
200.Saucrobotys futilalis	Dogbane saucrobotys moth	*Apocynum sp.*	*Dogbane*
201.Schinia nubila	Camphorweed flower moth	*Solidago sp.*	*Goldenrod*
202.Schinia nundina	Goldenrod flower moth	*Solidago sp.*	*Goldenrod*
203.Schreckensteinia festaliella	Blackberry skeletonizer	*Rubus sp.*	*Blackberry*
204.Scrobipalpula artemisiella	Thyme moth	*Solidago sp.*	*Goldenrod*
205.Selenia kentaria	Kent's geometer	*Acer rubrum*	*Red maple*
206.Sphecodina abbottii	Abbott's sphinx	*Parthenocissus quinquefolia*	*Virginia creeper*
207.Sphinx gordius	No common name	*Comptonia peregrina*	*Sweet ferm*
208.Sphinx chersis	Great ash sphinx	*Prunus serotina*	*Black cherry*
209.Sphinx drupiferarum	Wild cherry sphinx	*Prunus serotina*	*Black cherry*
210.Sphinx eremitus	Hermit sphinx	*Mentha sp.*	*Mint*
211.Stretchia plusiiformis	No common name	*Ribes uva-crispa*	*Gooseberry*
212.Strymon melinus	Gray hairstreak	*Menth sp.*	*Mint*
213.Symmerista leucitys	Orange-humped maple worm moth	*Acer rubrum*	*Red maple*
214.Synanthedon acerni	Maple callus borer	*Acer rubrum*	*Red maple*
215.Synanthedon pictipes	Lesser peachtree borer	*Prunus serotina*	*Black cherry*
216.Synchlora aerata	Camouflaged looper	*Solidago sp.*	*Goldenrod*
217.Tischeria splendida	No common name	*Rubus sp.*	*Blackberry*
218.Tolype velleda	Large tolype moth	*Prunus serotina*	*Black cherry*
219.Tricholita notata	No common name	*Solidago sp.*	*Goldenrod*
220.Trichoptilus lobidactylus	No common name	*Solidago sp.*	*Goldenrod*
221.Trichordestra tacoma	No common name	*Apocynum sp.*	*Dogbane*
222.Vanessa cardui	Painted Lady	*Mentha sp.*	*Mint*
223.Vitacea scepsiformis	Lesser grape root borer moth	*Parthenocissus quinquefolia, Vitis*	*Virginia creeper, grape*
224.Zale lunata	Lunate zale	*Prunus serotina*	*Black cherry*
225.Zophodia convolutella	Gooseberry fruit worm moth	*Ribes uva-crispa*	*Gooseberry*

* denotes non-native plant species or only KNOWN larval host species; all larval host species of many Lepidoptera are not known.

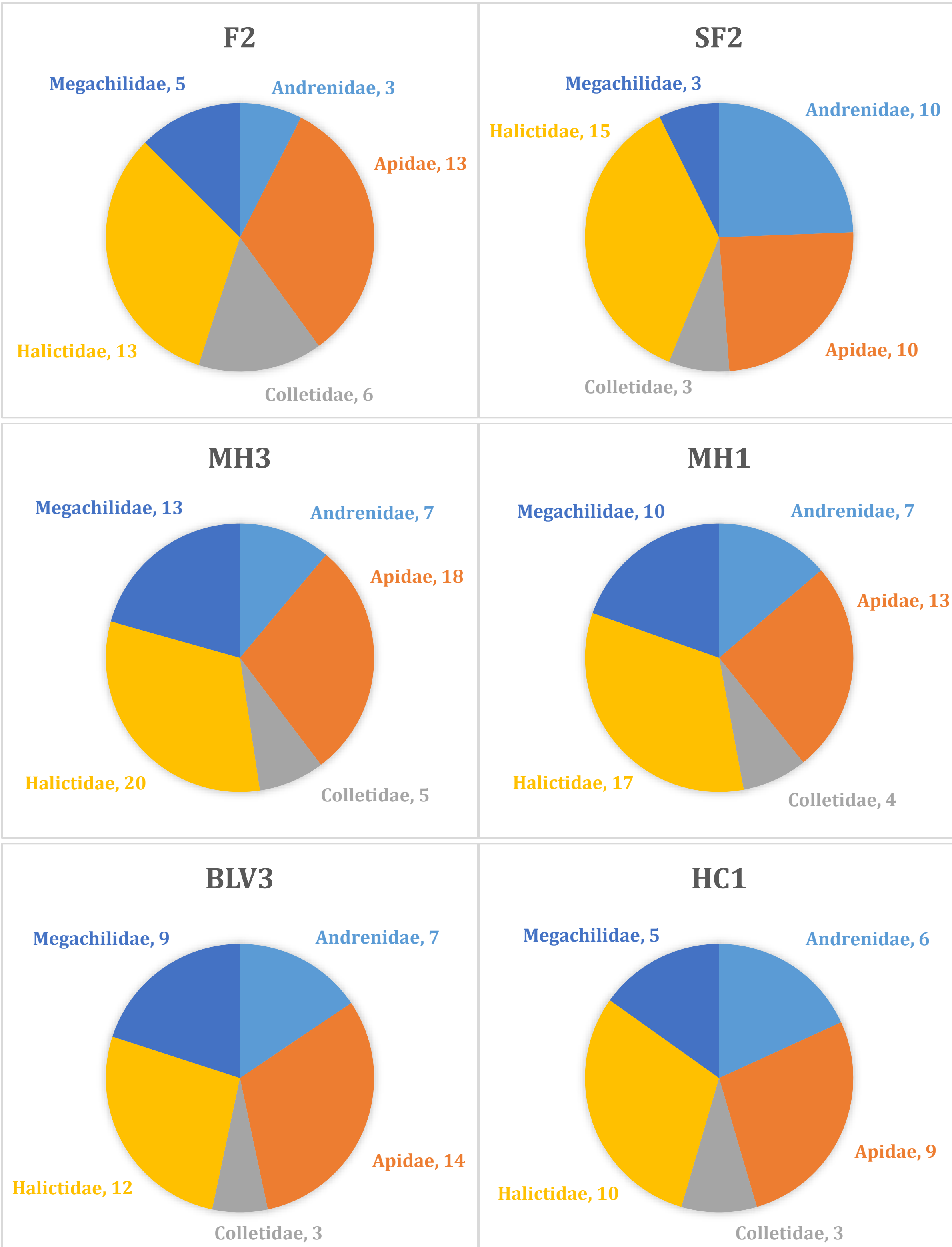
Appendix D. Family abundance and taxa richness of bees per plot at SGL 33 for 2017.

MAY - AUGUST 2017	**SGL 33** *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
ANDRENIDAE (mining bees)						
Number of Andrenidae Individuals Per Site	5	76	13	24	34	9
Number of Andrenidae Taxa Per Site	**3**	**10**	**7**	**7**	**7**	**6**
APIDAE (cuckoo/carpenter/digger bees, bumblebees and honeybees)						
Number of Apidae Individuals Per Site	128	99	145	31	245	33
Number of Apidae Taxa Per Site	**13**	**10**	**18**	**13**	**14**	**9**
COLLETIDAE (plasterer/masked bees)						
Number of Colletidae Individuals Per Site	19	15	24	19	8	19
Number of Colletidae Taxa Per Site	**6**	**3**	**5**	**4**	**3**	**3**
HALICTIDAE (sweat bees)						
Number of Halictidae Individuals Per Site	39	73	58	54	36	24
Number of Halictidae Taxa Per Site	**13**	**15**	**20**	**17**	**12**	**10**
MEGACHILIDAE (leaf-cutter/mason bees)						
Number of Megachilidae Individuals Per Site	5	3	16	15	13	5
Number of Megachilidae Taxa Per Site	**5**	**3**	**13**	**10**	**9**	**5**
MELITTIDAE (oil-collecting bees)						
Number of Melittidae Individuals Per Site	1	0	0	0	0	0
Number of Melittidae Taxa Per Site	**1**	**0**	**0**	**0**	**0**	**0**
TOTAL INDIVIDUAL BEES PER SITE	197	266	256	143	336	90
TOTAL BEE TAXA PER SITE	**41**	**41**	**63**	**51**	**45**	**33**
NUMBER OF BEE FAMILIES REPRESENTED PER SITE	*6*	*5*	*5*	*5*	*5*	*5*

SGL 33 - 2017 - BEE FAMILY ABUNDANCE PER PLOT
(FAMILY, NUMBER OF *INDIVIDUALS* PER FAMILY)



SGL 33 - 2017 - BEE FAMILY TAXA RICHNESS PER PLOT
(FAMILY, NUMBER OF *INDIVIDUALS* PER FAMILY)



SGL 33 - 2017 - Abundance of Individual Bees and Bee Taxa Totals

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
ANDRENIDAE (mining bees)						
***Andrena* sp.** (a mining bee)						
Andrena bradleyi ("Bradley's mining bee")				1		
Andrena brevipalpis						
Andrena brevipalpis/robertsonii						
Andrena carlini ("Carlin's mining bee")		6	1		7	
Andrena carolina ("Carolina mining bee")		5	2		10	1
Andrena ceanothi		1		14	2	
Andrena commoda (a mining bee)						
Andrena crataegi ("Hawthorn mining bee")						
Andrena cressonii ("Cresson's mining bee")						
Andrena forbesii ("Forbes' mining bee")			1			
Andrena hirticincta ("hairy-banded mining bee")	1	2	2			
Andrena imitatrix						1
Andrena krigiana ("dwarf-dandelion mining bee")						
Andrena mandibularis						
Andrena milwaukeensis ("Milwaukee mining bee")						2
Andrena miserabilis ("miserable mining bee")						
Andrena nasonii ("Nason's mining bee")			1			
Andrena nivalis ("snowy mining bee")		2		2		3
Andrena nubecula ("cloudy-winged mining bee")	1					
Andrena personata						
Andrena pruni (a mining bee)						
Andrena robertsonii						
Andrena rugosa ("rugose mining bee")						
Andrena sayi ("Say's mining bee")						

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
ANDRENIDAE (mining bees)	(continued)					
Andrena spiraeana	3			1	1	
Andrena tridens						
Andrena truncatum (valid? IDed by Sam for F2, 2016)						
Andrena vicina ("neighborly mining bee")		3		1	8	
Andrena virginiana ("Virginia mining bee")		***50***	4	1		
Andrena wilkella ("Wilke's mining bee")		1		4	4	1
Andrena ziziaeformis (a mining bee)		1	2		2	1
***Andrena* (Trachandrena) sp.** (a mining bee)		5				
Calliopsis andreniformis						
APIDAE (cuckoo/carpenter/digger bees, bumble bees and honey bees)						
***Anthophora* sp.** (long-horned digger bees)						
Anthophora abrupta (abrupt digger bee)						
Anthophora bomboides (bumble-bee digger bee)						
Apis mellifera ("European honey bee")			5		9	6
***Bombus* sp.** (unspecified bumble bee)						
Bombus bimaculatus ("two-spotted bumble bee")	***67***	2	7	1	14	
Bombus fernaldae ("Fernald's cuckoo bumble bee")						
****Bombus fervidus*** ("yellow bumble bee" ****VULNERABLE***)			2			
Bombus griseocollis ("brown-belted bumble bee")		2	1			
Bombus impatiens ("common eastern bumble bee")	12	45	30	4	***179***	6
Bombus perplexus ("confusing/perplexing bumble bee")			1			1
****Bombus sandersoni*** ("Sanderson's bumble bee" ***UNCOMMON**)	1					
Bombus vagans ("half-black bumble bee")	19	3	17	2	7	
***Ceratina* sp.** (small carpenter bee)	4	1	5	3	3	
Ceratina calcarata ("spurred small carpenter bee")	3	4	7		1	5

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
APIDAE (cuckoo/carpenter/digger bees, bumble bees and honey bees)	(continued)					
Ceratina dupla ("doubled small carpenter bee")	10	38	***43***	4	16	9
Ceratina miqmaki ("Miqmak small carpenter bee")	6	2	11	3	3	3
Ceratina strenua ("nimble small carpenter bee")	2		7	3	3	1
Epeolus scutellaris ("notch-backed cellophane-cuckoo bee")	1			2		
***Holcopasites* sp.** (a cuckoo bee)						
***Melissodes* sp.** (a longhorned bee)			1			
****Melissodes apicatus** (*new state record for PA, 2017)*						
Melissodes druriellus (a longhorned bee)	1					
Melissodes illatus/subillatus (a longhorned bee)				3		
Melissodes trinodis						
Nomadinae						
***Nomada* sp.** (a nomad bee)						
***Nomada bidentata* group**		1	1	1	1	
Nomada cressonii ("Cresson's nomad bee")						
Nomada denticulata			1			
Nomada imbricata				1		
Nomada luteoloides				1		
Nomada maculata ("spotted nomad bee")				3	4	
Nomada pygmaea ("pygmy nomad bee")	1		2		2	1
Nomada sayi/illinoensis						
Nomada vicina	1		1			
****Nomada xanthura** (*new state record for PA, 2017)*		1				
Peponapis pruinosa (squash bee, "Eastern cucurbit bee")						
Triepeolus donatus (a cuckoo bee)					1	
Xylocopa virginica ("eastern/large carpenter bee")			3		2	1

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
COLLETIDAE (plasterer bees, masked/yellow-faced bees)						
***Colletes* sp.** (a cellophane/polyester bee)						
Colletes simulans ("spine-shouldered cellophane bee")	1	1	4			
Colletes thoracicus ("rufous-chested cellophane bee")						
Colletes validus ("blueberry cellophane bee")						
***Hylaeus* sp.** (a masked/yellow-faced bee)						
Hylaeus affinis ("eastern masked bee")	1			1		
Hylaeus affinis/modestus ("eastern/modest masked bee")	6	13	12	12	3	9
Hylaeus annulatus ("annulate masked bee")	1	1	2			
Hylaeus mesillae ("Mesilla masked bee")	7		3	4	3	5
Hylaeus modestus ("modest masked bee")	3		3	2	2	5
HALICTIDAE (sweat bees)						
Agapostemon virescens ("bicolored striped sweat bee")						
Augochlora pura ("pure green sweat bee")	3	3	2	2	1	3
Augochlorella aurata (a metallic green sweat bee)	4	5	7	8	4	3
***Augochloropsis* sp.** (a metallic green sweat bee)						
Augochloropsis metallica						
Augochloropsis metallica fulgida		1	2	2	1	***11***
***Halictus* sp.** (an end-banded furrow bee)						
Halictus confusus ("confusing" or "Southern bronze" furrow bee)	2	1	5	1	1	
Halictus ligatus ("ligated furrow bee")			7	2	14	
Halictus rubicundus ("orange-legged furrow bee")		2	1			
***Lasioglossum* sp.** (a base-banded furrow bee)	2	2		1		
Lasioglossum abanci						
Lasioglossum acuminatum					1	

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
HALICTIDAE (sweat bees)	(continued)					
Lasioglossum albipenne ("white-winged metallic sweat bee")				1		
Lasioglossum apocyni	1	4	1	4	1	1
Lasioglossum cinctipes				1		
Lasioglossum coeruleum						
Lasioglossum coriaceum	1	2		1		1
Lasioglossum cressonii ("Cresson's Dialictus sweat bee")	18	12	11	***23***	9	
Lasioglossum ephialtum	1				1	1
Lasioglossum foxii	1					
Lasioglossum fuscipenne						
Lasioglossum heterognathum		26	8		1	1
Lasioglossum hitchensi	1		2	2		
Lasioglossum illinoense						
Lasioglossum imitatum						
Lasioglossum laevissimum						1
Lasioglossum leucocomum				1		
Lasioglossum leucozonium ("white-zoned mining/furrow bee")			1			
Lasioglossum lineatulum ("lineated metallic sweat bee")		1	1			
Lasioglossum nigroviride ("black and green Dialictus sweat bee")		2				
Lasioglossum paradmirandum						
Lasioglossum perpunctatum			1			
Lasioglossum quebecense (a nocturnal sweat bee)					1	
Lasioglossum subviridatum			1			
Lasioglossum tegulare ("epaulette metallic sweat bee")						
Lasioglossum timothyi				1		

MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
HALICTIDAE (sweat bees)	(continued)					
Lasioglossum trigeminum		2				
Lasioglossum truncatum			1			
Lasioglossum versans	3	9	2	1		
Lasioglossum versatum			1			1
Lasioglossum zonulum	1					
***Sphecodes* sp.** (a cuckoo bee)	1	1	1	2	1	
Sphecodes coronus			1			
****Sphecodes galerus (*possible new state record for PA, 2017)***				1		1
Sphecodes heraclei			2			
MEGACHILIDAE (leaf-cutter bees, mason bees)						
***Coelioxys* sp.** (cuckoo leaf-cutter bee)						
Coelioxys modesta/modestus ("modest cuckoo leafcutter bee")						1
Coelioxys moesta/moestus (a cuckoo leafcutter bee)			1			
Coelioxys octodentata ("eight-toothed cuckoo leaf-cutter bee")						
Coelioxys rufitarsis ("red-footed cuckoo leaf-cutter bee")					1	1
Coelioxys sayi ("Say's cuckoo leaf-cutter bee")			1			
***Heriades* sp.** (a leaf-cutter bee)						
Heriades carinata	1		2	3		
****Heriades leavitti (*new state record for PA, 2016*)**	1				1	
Heriades leavitti/variolosa						
***Hoplitis* sp.** (a leaf-cutter bee)						
Hoplitis pilosifrons			2	1		
Hoplitis producta	1		1	2	1	
Hoplitis spoilata		1				
***Megachile* sp.** (a leafcutter/resin bee)						
Megachile brevis ("common little leafcutter bee")						

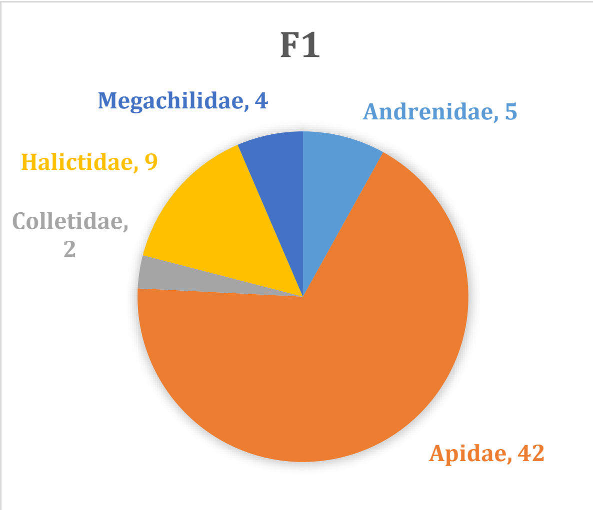
MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
MEGACHILIDAE (leaf-cutter bees, mason bees)	(continued)					
Megachile campanulae ("bellflower resin bee")						1
Megachile gemula ("small-handed leafcutter bee")			1		1	
Megachile inermis ("unarmed leafcutter bee")			1			
Megachile inimica ("hostile leafcutter bee")					1	
Megachile latimanus ("broad-handed leafcutter bee")					3	
Megachile mendica ("flat-tailed leafcutter bee")			1	2	1	1
Megachile montivaga ("silver-tailed petalcutter bee")	1	1		1		
Megachile pugnata ("pugnacious leafcutter bee")			1			
Megachile relativa ("golden-tailed leafcutter bee")			2	1	3	
Megachile sculpturalis ("giant/sculptured resin bee")			1			
***Osmia* sp.** (a mason bee)						
Osmia atriventris ("Maine blueberry bee")	1	1		2	1	1
Osmia bucephala ("bufflehead mason bee")				1		
Osmia collinsiae				1		
Osmia cornifrons ("hornfaced bee")						
Osmia distincta						
Osmia georgica			1			
Osmia inspergens						
Osmia lignaria ("blue orchard bee")						
Osmia pumila			1	1		
Osmia taurus ("taurus/bull mason bee")						
MELITTIDAE** (oil-collecting bees ****RARE)						
****Macropis ciliata*** ("ciliary oil-collecting bee")	1					

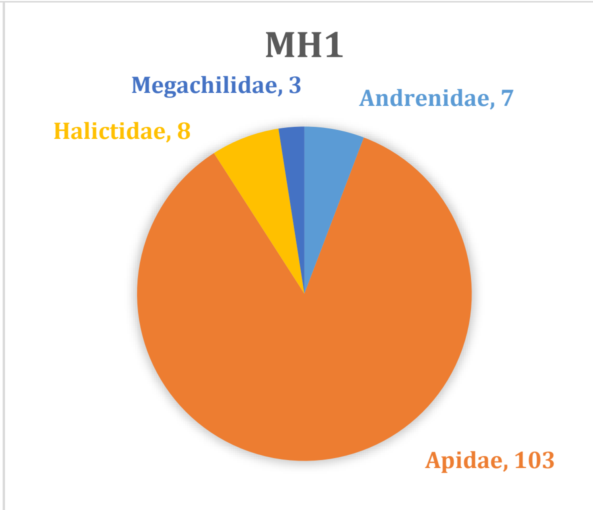
MAY - AUGUST 2017	SGL 33 *(16 total net hours per plot)*					
BEE TAXA	**F2**	**SF2**	**MH3**	**MH1**	**BLV3**	**HC1**
TOTAL INDIVIDUAL BEES PER SITE	197	266	256	143	**336**	**90**
TOTAL BEE TAXA PER SITE	58	47	**69**	57	51	**39**
	traditional pollinator					
	cleptoparasitic taxon or taxa					
	introduced species					
Green text	**new to SGL33 collection**					
Blue text	**only at Green Lane (2017)**					

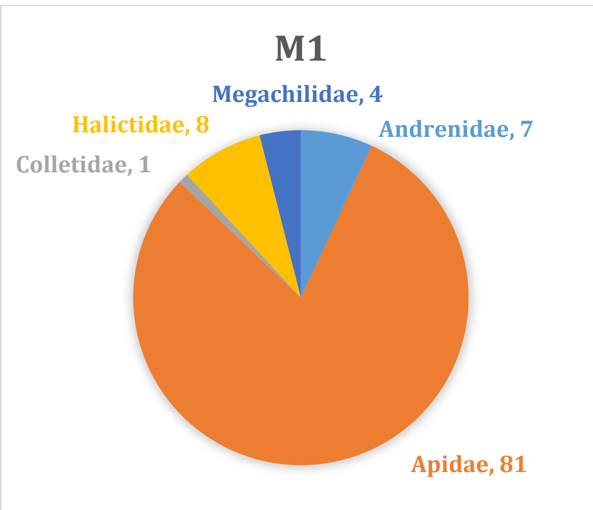
Appendix E. Family abundance and taxa richness of bees per plot at GLR&D for 2017.

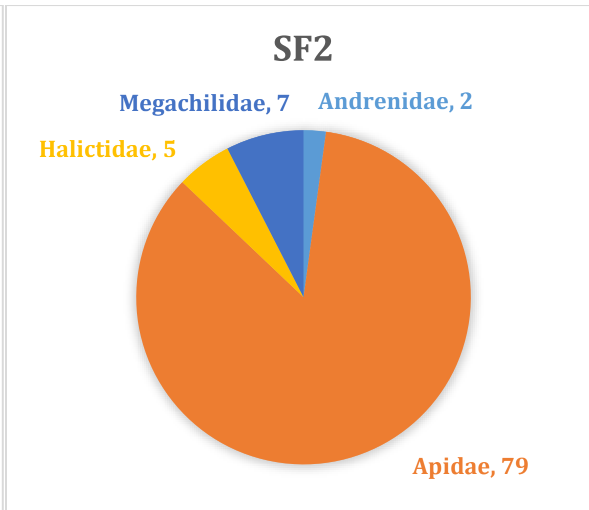
MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
ANDRENIDAE (mining bees)					
Number of Andrenidae Individuals Per Site	5	7	7	2	0
Number of Andrenidae Taxa Per Site	**4**	**4**	**5**	**2**	**0**
APIDAE (cuckoo/carpenter/digger bees, bumblebees and honeybees)					
Number of Apidae Individuals Per Site	42	103	81	79	70
Number of Apidae Taxa Per Site	**11**	**5**	**7**	**10**	**8**
COLLETIDAE (plasterer/masked bees)					
Number of Colletidae Individuals Per Site	2	0	1	0	0
Number of Colletidae Taxa Per Site	**1**	**0**	**1**	**0**	**0**
HALICTIDAE (sweat bees)					
Number of Halictidae Individuals Per Site	9	8	8	5	5
Number of Halictidae Taxa Per Site	**5**	**6**	**6**	**5**	**3**
MEGACHILIDAE (leaf-cutter/mason bees)					
Number of Megachilidae Individuals Per Site	4	3	4	7	2
Number of Megachilidae Taxa Per Site	**4**	**3**	**3**	**3**	**2**
MELITTIDAE (oil-collecting bees)					
Number of Melittidae Individuals Per Site	0	0	0	0	0
Number of Melittidae Taxa Per Site	**0**	**0**	**0**	**0**	**0**
TOTAL INDIVIDUAL BEES PER SITE	62	121	101	93	77
TOTAL BEE TAXA PER SITE	**25**	**18**	**22**	**20**	**13**
NUMBER OF BEE FAMILIES REPRESENTED PER SITE	*5*	*4*	*5*	*4*	*3*

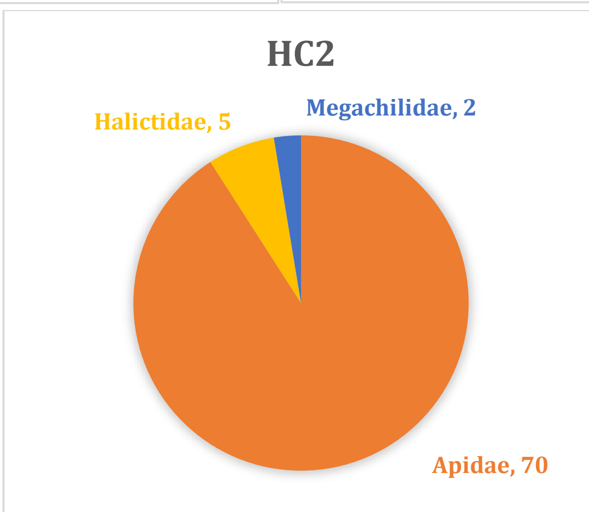
GLR&D - 2017 - BEE FAMILY ABUNDANCE PER PLOT
(FAMILY, NUMBER OF *INDIVIDUALS* PER FAMILY)



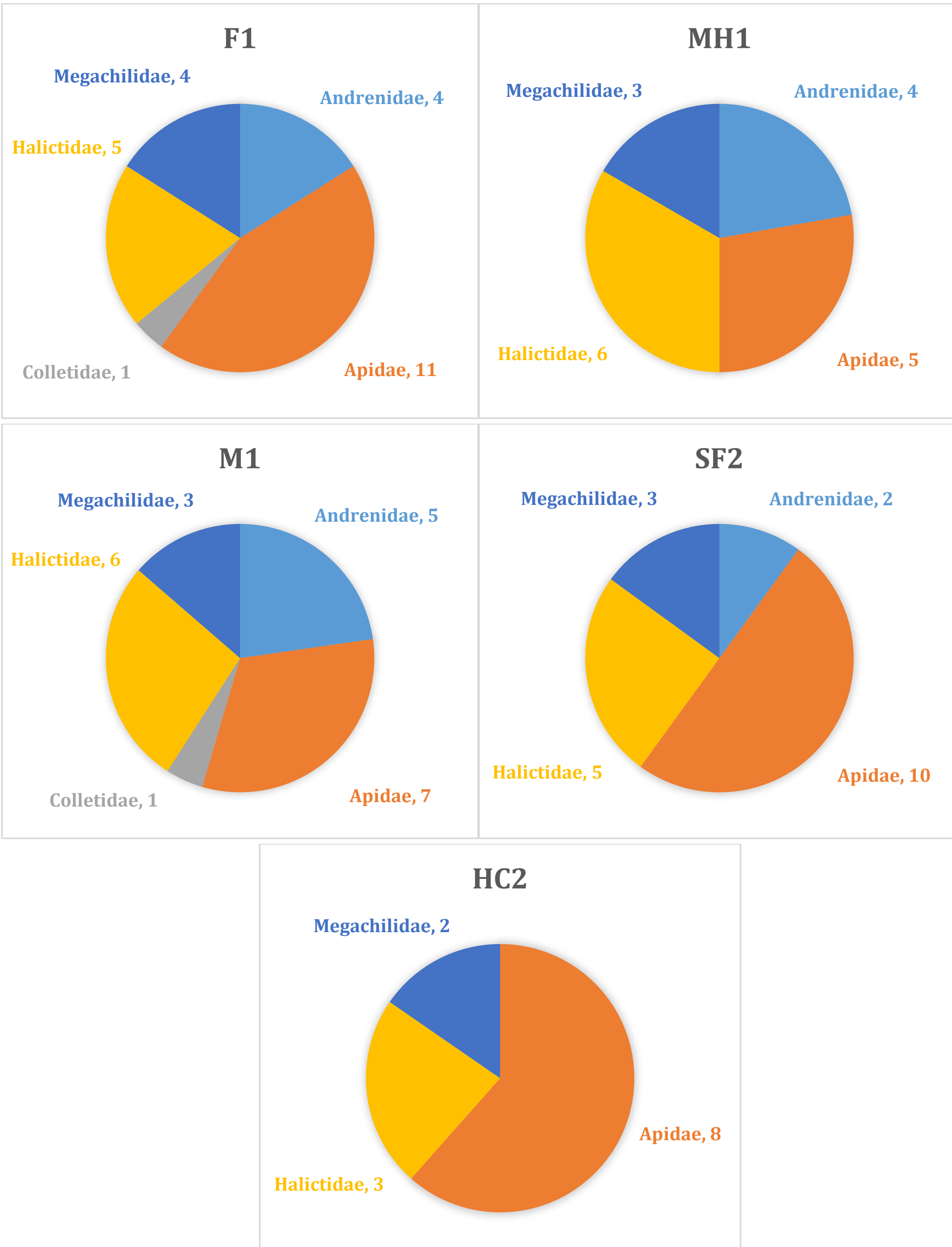








GLR&D - 2017 - BEE FAMILY TAXA RICHNESS PER PLOT
(FAMILY, NUMBER OF *INDIVIDUALS* PER FAMILY)



GLR&D - 2017 - Abundance of Individual Bees and Bee Taxa Totals

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
ANDRENIDAE (mining bees)					
***Andrena* sp.** (a mining bee)					
Andrena bradleyi ("Bradley's mining bee")					
Andrena brevipalpis					
Andrena brevipalpis/robertsonii			1		
Andrena carlini ("Carlin's mining bee")		2			
Andrena carolina ("Carolina mining bee")					
Andrena ceanothi					
Andrena commoda (a mining bee)	1	1			
Andrena crataegi ("Hawthorn mining bee")	1	1			
Andrena cressonii ("Cresson's mining bee")			2		
Andrena forbesii ("Forbes' mining bee")					
Andrena hirticincta ("hairy-banded mining bee")					
Andrena imitatrix					
Andrena krigiana ("dwarf-dandelion mining bee")			1		
Andrena mandibularis					
Andrena milwaukeensis ("Milwaukee mining bee")					
Andrena miserabilis ("miserable mining bee")					
Andrena nasonii ("Nason's mining bee")		3	1	1	
Andrena nivalis ("snowy mining bee")					
Andrena nubecula ("cloudy-winged mining bee")					
Andrena personata					
Andrena pruni (a mining bee)	1				
Andrena robertsonii	2		2		
Andrena rugosa ("rugose mining bee")					
Andrena sayi ("Say's mining bee")				1	

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
ANDRENIDAE (mining bees)	(continued)				
Andrena spiraeana					
Andrena tridens					
Andrena truncatum (valid? IDed by Sam for F2, 2016)					
Andrena vicina ("neighborly mining bee")					
Andrena virginiana ("Virginia mining bee")					
Andrena wilkella ("Wilke's mining bee")					
Andrena ziziaeformis (a mining bee)					
***Andrena* (Trachandrena) sp.** (a mining bee)					
Calliopsis andreniformis					
APIDAE (cuckoo/carpenter/digger bees, bumble bees and honey bees)					
***Anthophora* sp.** (long-horned digger bees)					
Anthophora abrupta (abrupt digger bee)				2	
Anthophora bomboides (bumble-bee digger bee)				2	
Apis mellifera ("European honey bee")	3	15	10	17	20
***Bombus* sp.** (unspecified bumble bee)					
Bombus bimaculatus ("two-spotted bumble bee")	1		4	2	1
Bombus fernaldae ("Fernald's cuckoo bumble bee")					
Bombus fervidus ("yellow bumble bee" ***VULNERABLE***)					
Bombus griseocollis ("brown-belted bumble bee")	6	11	6	9	1
Bombus impatiens ("common eastern bumble bee")	***21***	***72***	***54***	***37***	***36***
Bombus perplexus ("confusing/perplexing bumble bee")	1			1	
Bombus sandersoni ("Sanderson's bumble bee" ***UNCOMMON**)					
Bombus vagans ("half-black bumble bee")					
***Ceratina* sp.** (small carpenter bee)					
Ceratina calcarata ("spurred small carpenter bee")					

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
APIDAE (cuckoo/carpenter/digger bees, bumble bees and honey bees)	(continued)				
Ceratina dupla ("doubled small carpenter bee")			1	1	1
Ceratina miqmaki ("Miqmak small carpenter bee")	3		1		
Ceratina strenua ("nimble small carpenter bee")	1				4
Epeolus scutellaris ("notch-backed cellophane-cuckoo bee")					
***Holcopasites* sp.** (a cuckoo bee)					
***Melissodes* sp.** (a longhorned bee)					
****Melissodes apicatus*** ***(*new state record for PA, 2017)***				4	
Melissodes druriellus (a longhorned bee)					
Melissodes illatus/subillatus (a longhorned bee)					
Melissodes trinodis					
Nomadinae	1				
***Nomada* sp.** (a nomad bee)	1				
***Nomada bidentata* group**	1				1
Nomada cressonii ("Cresson's nomad bee")					
Nomada denticulata					
Nomada imbricata					
Nomada luteoloides					
Nomada maculata ("spotted nomad bee")					
Nomada pygmaea ("pygmy nomad bee")					
Nomada sayi/illinoensis		1			
Nomada vicina					
****Nomada xanthura*** ***(*new state record for PA, 2017)***					
Peponapis pruinosa (squash bee, "Eastern cucurbit bee")					
Triepeolus donatus (a cuckoo bee)					
Xylocopa virginica ("eastern/large carpenter bee")	3	4	5	4	6

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
COLLETIDAE (plasterer bees, masked/yellow-faced bees)					
***Colletes* sp.** (a cellophane/polyester bee)					
Colletes simulans ("spine-shouldered cellophane bee")					
Colletes thoracicus ("rufous-chested cellophane bee")			1		
Colletes validus ("blueberry cellophane bee")					
***Hylaeus* sp.** (a masked/yellow-faced bee)					
Hylaeus affinis ("eastern masked bee")					
Hylaeus affinis/modestus ("eastern/modest masked bee")	2				
Hylaeus annulatus ("annulate masked bee")					
Hylaeus mesillae ("Mesilla masked bee")					
Hylaeus modestus ("modest masked bee")					
HALICTIDAE (sweat bees)					
Agapostemon virescens ("bicolored striped sweat bee")	2		1		
Augochlora pura ("pure green sweat bee")		2	1		
Augochlorella aurata (a metallic green sweat bee)		2	3	1	1
***Augochloropsis* sp.** (a metallic green sweat bee)					
Augochloropsis metallica					
Augochloropsis metallica fulgida					
***Halictus* sp.** (an end-banded furrow bee)					
Halictus confusus ("confusing" or "Southern bronze" furrow bee)					
Halictus ligatus ("ligated furrow bee")	1				
Halictus rubicundus ("orange-legged furrow bee")		1			
***Lasioglossum* sp.** (a base-banded furrow bee)		1		1	
Lasioglossum abanci					
Lasioglossum acuminatum					
Lasioglossum albipenne ("white-winged metallic sweat bee")					
Lasioglossum apocyni	1			1	

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
HALICTIDAE (sweat bees)	(continued)				
Lasioglossum cinctipes					
Lasioglossum coeruleum				1	
Lasioglossum coriaceum			1		
Lasioglossum cressonii ("Cresson's Dialictus sweat bee")					
Lasioglossum ephialtum	4	1		1	
Lasioglossum foxii					
Lasioglossum fuscipenne		1			2
Lasioglossum heterognathum					
Lasioglossum hitchensi					
Lasioglossum illinoense	1		1		
Lasioglossum imitatum					
Lasioglossum laevissimum					
Lasioglossum leucocomum					
Lasioglossum leucozonium ("white-zoned mining/furrow bee")					
Lasioglossum lineatulum ("lineated metallic sweat bee")					
Lasioglossum nigroviride ("black and green Dialictus sweat bee")					
Lasioglossum paradmirandum					
Lasioglossum perpunctatum					
Lasioglossum quebecense (a nocturnal sweat bee)			1		
Lasioglossum subviridatum					
Lasioglossum tegulare ("epaulette metallic sweat bee")					
Lasioglossum timothyi					
Lasioglossum trigeminum					
Lasioglossum truncatum					
Lasioglossum versans					

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
HALICTIDAE (sweat bees)	(continued)				
Lasioglossum versatum					2
Lasioglossum zonulum					
***Sphecodes* sp.** (a cuckoo bee)					
Sphecodes coronus					
****Sphecodes galerus (*possible new state record for PA, 2017)***					
Sphecodes heraclei					
MEGACHILIDAE (leaf-cutter bees, mason bees)					
***Coelioxys* sp.** (cuckoo leaf-cutter bee)					
Coelioxys modesta/modestus ("modest cuckoo leafcutter bee")					
Coelioxys moesta/moestus (a cuckoo leafcutter bee)					
Coelioxys octodentata ("eight-toothed cuckoo leaf-cutter bee")					
Coelioxys rufitarsis ("red-footed cuckoo leaf-cutter bee")					
Coelioxys sayi ("Say's cuckoo leaf-cutter bee")					
***Heriades* sp.** (a leaf-cutter bee)					
Heriades carinata					
****Heriades leavitti*** (****new state record for PA, 2016***)					
Heriades leavitti/variolosa					
***Hoplitis* sp.** (a leaf-cutter bee)					
Hoplitis pilosifrons				1	
Hoplitis producta	1				
Hoplitis spoilata					
***Megachile* sp.** (a leafcutter/resin bee)					
Megachile brevis ("common little leafcutter bee")		1			
Megachile campanulae ("bellflower resin bee")					
Megachile gemula ("small-handed leafcutter bee")					

MAY - JULY 2017	GLR&D *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
MEGACHILIDAE (leaf-cutter bees, mason bees)	(continued)				
Megachile inermis ("unarmed leafcutter bee")					
Megachile inimica ("hostile leafcutter bee")					
Megachile latimanus ("broad-handed leafcutter bee")					
Megachile mendica ("flat-tailed leafcutter bee")		1	2		
Megachile montivaga ("silver-tailed petalcutter bee")	1		1	4	1
Megachile pugnata ("pugnacious leafcutter bee")					
Megachile relativa ("golden-tailed leafcutter bee")					
Megachile sculpturalis ("giant/sculptured resin bee")					
***Osmia* sp.** (a mason bee)					
Osmia atriventris ("Maine blueberry bee")	1				
Osmia bucephala ("bufflehead mason bee")					
Osmia collinsiae					
Osmia cornifrons ("hornfaced bee")	1				
Osmia distincta			1	2	1
Osmia georgica					
Osmia inspergens					
Osmia lignaria ("blue orchard bee")		1			
Osmia pumila					
Osmia taurus ("taurus/bull mason bee")					
MELITTIDAE** (oil-collecting bees ****RARE)					
****Macropis ciliata*** ("ciliary oil-collecting bee")					

MAY - JULY 2017	**GLR&D** *(6 total net hours per plot)*				
BEE TAXA	**F1**	**MH1**	**M1**	**SF2**	**HC2**
TOTAL INDIVIDUAL BEES PER SITE	**62**	**121**	101	93	77
TOTAL BEE TAXA PER SITE	**42**	24	28	26	**19**
	traditional pollinator				
	cleptoparasitic taxon or taxa				
	introduced species				
Green text	**new to SGL33 collection**				
Blue text	**only at Green Lane (2017)**				