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The potential conservation value of unmowed powerline strips for native bees

K.N. Russell [a,*], H. Ikerd [b], S. Droege [c]

[a] *Division of Invertebrate Zoology, American Museum of Natural History, Central Park West, 79th Street, New York, NY 10024, USA*
[b] *Bee Biology and Systematics Laboratory, Utah State University, 5310 Old Main Hill, Logan, UT 84322-5310, USA*
[c] *USGS Patuxent Wildlife Research Center, 12100 Beech Forest, Laurel, MD 20708-4083, USA*

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Abstract

The land area covered by powerline easements in the United States exceeds the area of almost all national parks, including Yellowstone. In parts of Europe and the US, electric companies have altered their land management practices from periodic mowing to extraction of tall vegetation combined with the use of selective herbicides. To investigate whether this alternate management practice might produce higher quality habitat for native bees, we compared the bee fauna collected in unmowed powerline corridors and in nearby mowed grassy fields at the Patuxent Wildlife Research Center (MD). Powerline sites had more spatially and numerically rare species and a richer bee community than the grassy fields, although the difference was less pronounced than we expected. Powerline sites also had more parasitic species and more cavity-nesting bees. Bee communities changed progressively through the season, but differences between the site types were persistent. The surrounding, non-grassland landscape likely has a strong influence on the bee species collected at the grassland sites, as some bees may be foraging in the grasslands but nesting elsewhere. Improving habitat for native bees will help ameliorate the loss of pollination services caused by the collapse of wild and managed honeybee populations. This study suggests that powerline strips have the potential to provide five million acres of bee-friendly habitat in the US if utilities more generally adopt appropriate management practices.

Keywords: Native bees; Powerline corridors; Rights-of-way; Vegetation management; Species richness; Nesting habitat

1. Introduction

1.1. Importance of wild bees

There are roughly 20,000 species of bees described to date (Michener, 2000), and this number is likely to continue to grow as biodiversity collections intensify in the developing world. Based on species number alone, this group represents a substantial component of biodiversity worldwide. Additionally, bees are widely recognized as one of the main providers of pollination services. Second only to wind as transporters of pollen, bee activities not only provide a necessary component of reproduction for many flowering plants, but also enhance fruit set and size, seed production and viability, seedling vigor, and genetic diversity. This alone is sufficient cause for interest in the health of bee populations, but they are also critically important economically. Bees are responsible for the propagation of many garden flowers, most consumable fruits and vegetables, many fiber crops like flax and cotton, and forage crops such as alfalfa and clover. More than 66% of the world's 1500 crop species have one or more cultivars requiring visits by bees (Roubik, 1995), and it has been estimated that bees are required

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[*] Corresponding author. Tel.: +1 1212 769 5659; fax: +1 212 769 5277.
E-mail address: krussell@amnh.org (K.N. Russell).

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in some way for 15–30% of worldwide food production (McGregor, 1976). In 1980, the total value of bee-pollinated crops in the US was estimated at $18.9 billion (Levin, 1983). Evidence suggests that crop pollination in North America is accomplished by some combination of managed honeybees, wild honeybees and native bees (Michener, 2000; McGregor and Levin, 1970), though the relative contribution of each remains controversial. Based on a model by Southwick and Southwick (1992), the estimated value of non-honeybee pollinators to American agriculture is between $4.1 and $6.7 billion annually (Nabhan and Buchmann, 1997).

1.2. Bees in decline?

The number of managed colonies of honeybees reported on agricultural land in the US declined 57% from 1985 to 1997 (Nabhan and Donovan, 2000). Managed colonies in general have declined by almost 50% since 1945, by 25% during the 1990s alone (Allen-Wardell et al., 1998) and by 6.1% from 1999 to 2002 (www.usda.gov/nass/pubs/estindx2.htm). Information on feral honeybee colonies is rare and only available from small scale studies. One such study documented an 85% decline in colonies over a 10-year period (Loper, 1995). Although much of the decline of honeybees in this country and elsewhere can be attributed to species-specific causes such as mite infestations, disease, and the invasion from South America of Africanized honeybees, as well as increased efficiency in colony management and the ageing of the bee keeper population, it is likely that land alteration and pesticide use also play an important role. Regardless of the causes of the decline, it is no longer prudent to rely on a single species to provide the bulk of the pollination services required for agriculture and the reproduction of native plants. Just as we have perhaps given managed honeybee populations too much credit in terms of their contribution to agriculture in the US, we cannot assume that native bee populations will be able to spontaneously pick up the slack left by dwindling honeybee populations. It is likely that land-use changes and pesticides are having an effect on native bees as well. Evidence from Great Britain, Germany, Austria, Poland and Russia suggests that wild bee populations are in a state of serious decline, driven most likely by the intensification of agriculture and related activities (see O'Tool, 1993 for a review). Due to a lack of baseline data their status in North America has not been adequately documented, though it seems unlikely that the decline is a strictly European phenomenon.

1.3. Bees' needs

To thrive, bees need adequate floral resources in the form of pollen and nectar, an appropriate site to nest, and for some species, access to specific nest-building materials. These requirements are rarely all found in the same habitat, so bee species tend to make use of parts of multiple habitats within a landscape (Westrich, 1996). Historical farming practices were not necessarily a problem for most bees, as small crop fields provided additional foraging resources and abundant hedgerows, fencerows and field margins could provide much needed nesting habitat. However, modern agricultural practices have likely caused and will continue to cause much more severe obstacles for healthy bee populations, due to differences in the spatial aspect of modern fields (larger monocultures with less area conducive to nesting bees) as well as modern reliance on pesticides (Banaszak, 1996; Steffan-Dewenter et al., 2002; O'Tool, 1993). In addition to changes in the spatial arrangements of fields and the resultant decrease in the amount of suitable nesting habitat, the expansion of agricultural land devoted to grain crops – which are wind pollinated – greatly reduces the forage for wild bees in these areas (Cane and Tepedino, 2001). This is likely to be particularly relevant in parts of the midwestern United States where approximately 20% of the total land area is planted with these crops (www.nass.usda.gov). Certainly, wild bees in many areas are faced with reduced nesting and/or foraging options. On top of this, pesticide use is probably taking its own toll. There have been a few studies in North America that relate the application of insecticides to substantial reductions in seed and fruit production of local crops through the decimation of local bee populations (Johansen, 1977; Kevan and Plowright, 1989). Also, Kremen et al. (2002) found that the diversity and abundance of native bees was too low to effectively pollinate watermelon fields in areas either far from natural habitat or which made use of pesticides – only the fields of organic farms near refuge sites had adequate visitation. Though small in scale, these studies suggest that pesticide use and nest site availability can have a measurable effect on bee populations and therefore pollination. As wild bee populations are highly variable, it is likely that only a diverse fauna will offer the necessary redundancy to ensure adequate pollination from year to year (Cane and Payne, 1993; Roubik, 2001). This idea was corroborated by the study conducted in the Californian watermelon fields, where annual variability in species composition did not appear to affect pollination success in areas with high bee diversity (Kremen et al., 2002).

Outside of the agricultural landscape, urban development and sprawl is another likely cause of bee declines, through fragmentation effects and general reduction in habitat. A number of studies have documented declines in pollinator services in isolated natural habits (Pavlik et al., 1993; Percy and Cronk, 1997; Aizen and Feinsinger, 1994a,b; Steiner and Whitehead, 1996). It should be noted, however, that certain types of development may not be equally bad for all bee guilds (Cane, 2001) and therefore changes may not be immediately apparent when only considering species richness.

To summarize: bees need a diversity of foraging and nesting habitats, and flowering plants, either wild or planted, require a diverse bee community to ensure their reproduction. Numerous threats to the health of bee communities have been identified and so we have cause for concern. Supplementation of bee-friendly habitats should become a priority both for those interested in conserving native plants, those interested in agricultural productivity, and those interested in conserving the bees themselves.

1.4. Bee-friendly spaces?

The good news is that many bees do well in marginal and/or degraded habitats. Linear rights-of-way such as powerline easements have traditionally been thought of as an ecological negative. But in landscapes that lack sufficient early successional habitat, due to either re-forestation, agriculture or intensive development, such land could provide a valuable resource. Studies in Europe have concluded that bee diversity can be high in abandoned fields, roadsides, hedgerows, railway lines and other similar habitats (see Matheson et al., 1996), and that these areas can host source populations of many bee species, even if relatively small and surrounded by inhospitable development.

Although we are unaware of any studies directly addressing the effect of powerline rights-of-way on bee abundance and diversity, there is a growing body of evidence to suggest that they provide regionally important foraging and nesting sites for early successional bird and mammal species (Marshall and VanDruff, 2002; King and Byers, 2002; Marshall et al., 2002; Confer, 2002; Litvaitis, 2001; Macreadie et al., 1998; Knight and Kawashima, 1993; Johnson et al., 1979). The data on invertebrates are much less extensive. Despite many anecdotal reports indicating the value of powerline rights-of-way for insect species (entomologists and enthusiasts know to visit powerline ROW during collecting trips), quantitative data are sparse (but see Landham and Nichols, 2002; Barbour, 1997; Lowell and Lounsbury, 2002). Survey work suggests that rare species of insects in the Northeast are often, and sometimes only, found in utility corridors (D. Wagner, personal communication; T. Lautzenheiser, personal communication).

Some studies have found that powerline rights-of-way promote fragmentation and serve as barriers for certain vertebrate groups, but even in these cases, it is generally found that these effects are mitigated in areas where the vegetation is allowed to reach a certain density and/or the corridor is kept to a smaller width (Goldingay and Whelan, 1997; Goosem and Marsh, 1997). Within rights-of-way, bird abundance has been correlated with vegetation complexity (Kroodsma, 1982; Marshall and VanDruff, 2002), and a greater density and diversity of birds has been found in sites treated with selective herbicides compared to those that are periodically mowed (Confer, 2002). Finally, Marshall et al. (2002) concluded that although mowed sites had slightly higher avian density and nesting success compared with sites treated with selective herbicides, ultimately the mowed sites would be less valuable due to their lack of stability (the study was conducted several years after mowing, and the sites were due to be mowed again within the next two years, thereby destroying existing nesting habitat).

Currently, there is substantial variation in management practices in the US, as it is up to individual power companies how they manage their own land. Most powerline rights-of-way are periodically cleared of all vegetation either by mowing, herbicide application, or bush-hogging (mowing down of tall vegetation). In reaction to the backlash against the use of chemicals in the 1970s, most utilities initiated management strategies that involved periodic mowing exclusively. Recently many companies are attempting to move away from mowing and towards the use of *selective* herbicides and manual extraction of tall vegetation. This management strategy is ultimately more cost-effective, as site visits become less frequent over time due to the tree-repellant nature of the resulting dense scrub communities (Calvin Layton, NSTAR Senior Arborist, personal communication).

A recent study in Israel by Potts et al. (2003) found that the three most important determinants of local bee diversity were diversity of flower species, nesting substrate diversity and number of years post fire. Based on the availability of floral resources and potential nesting sites, we would predict that bee diversity would be highest in the stable, dense scrub habitat of unmowed rights-of-way. To investigate the utility of powerline rights-of-way as quality habitat for bees, we measured the bee communities of sites under powerlines located on the Patuxent Wildlife Research Center (PWRC) in Laurel, Maryland. Because only small sections of the rights-of-way on the refuge are mowed, we also surveyed bees in nearby, annually mowed fields as a point of comparison.

2. Methods

2.1. Study area

All sampling areas were located on the Patuxent Wildlife Research Center, a 5160 hectare National Wildlife Refuge surrounding the Patuxent and Little Patuxent Rivers between Washington, DC and Baltimore, MD. The reserve was developed specifically for wildlife research and encompasses a wide range of habitat types, including forest, meadow and wetland areas. Specifically, study sites were located in Anne Arundel County and Prince Georges County, Laurel, MD.

Two power companies have overhead transmission lines on Patuxent land. In the 1960s, Potomac Edison Power Company (PEPCO) constructed a 5.6 km overhead transmission line and in the early 1970s, Baltimore Gas and Electric (BG&E) constructed a new, 8.9 km overhead transmission line on Patuxent land adjacent to an existing facility. In conjunction with Patuxent scientists, BG&E and PEPCO developed vegetation management plans for the rights-of-way that would be least likely to negatively impact the resident or migrant wildlife community. These plans, though complex in detail, generally prohibit the use of non-selective herbicides and periodic mowing of the majority of land under the lines. Instead, management consists of periodic (every 4–5 years) selective basal spraying of tall growing trees, and the removal of all trees and topping of all shrubs greater than three meters. As a consequence, the habitat beneath the powerlines at Patuxent can be characterized as dense scrub in most areas, although there is considerable variation due to soil type and drainage. We did not conduct vegetation surveys in our study plots, but a general survey of the vegetation of the rights-of-way in the southern and central tracts of PWRC was conducted in 2000 (Bridgeland, 2001). The following 11 species were most commonly recorded: *Viburnum dentatum* (51), *Smilax rotundifolia* (49), *Vitus* spp. (30), *Gaylussacia frondosa* (29), *Gaylussacia baccata* (25), *Lyonia ligustrina* (19), *Rhus copallinum* (17), *Rosa multiflora* (17), *Ilex opaca* (16), *Eleagnus commutate* (16). Additional commonly occurring species with high stem densities were: *Vaccinium corymbosum*, *Lonicera japonica*, and *Amerlanchier arborea* (the figure in parentheses is the percentage of the 66, 1 × 10 m transects in which the species was detected).

The goal of the present study was to see if powerline rights-of-way managed for scrub could provide quality habitat for bee species and whether or not the quality of this habitat is superior to that provided by mowed powerline rights-of-way. We decided to restrict our sampling to the refuge for practical reasons and also because a secondary goal of this work was to compile a species list of bees for the area. Because of this decision, we did not have access to annually or bi-annually mowed powerline rights-of-way and so as a surrogate, we chose nearby annually mowed fields of comparable width. Fields were mowed shortly before sampling began in April.

2.2. Sampling design

Using a grid map of PWRC, we numbered all the available powerline sites along the two rights-of-way found on Patuxent property. We did the same for all known mowed field areas. We used a random number generator to select two powerline sites and two grassland sites in April, and three powerline and three grassland sites in each of May and June, for a total of 16 study sites (Fig. 1). It should be noted that

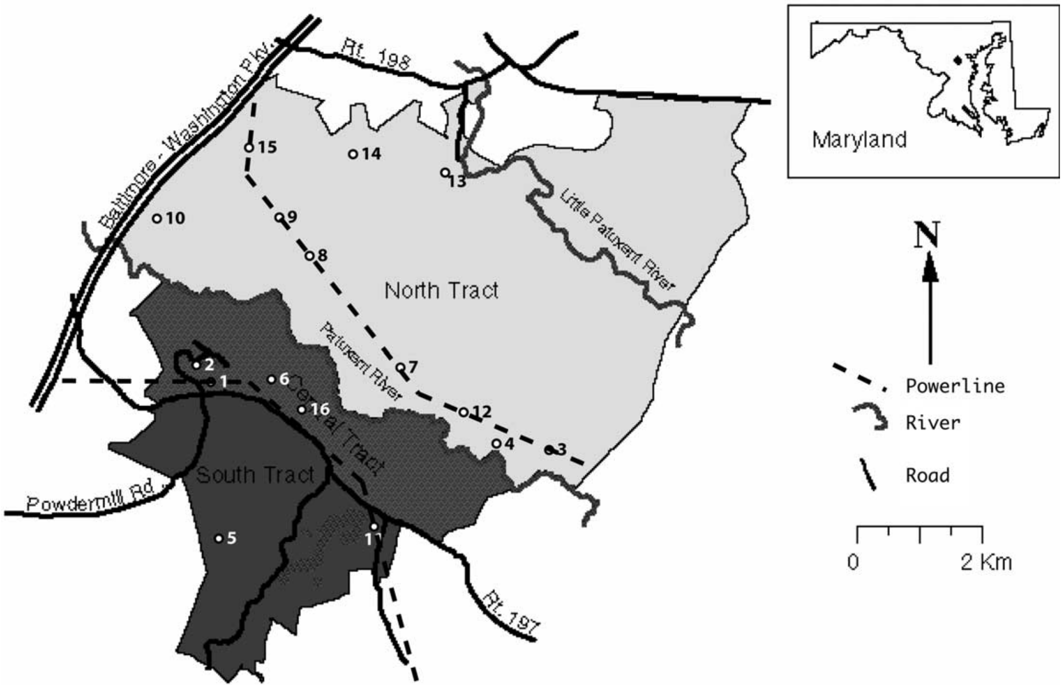

Fig. 1. Map of Patuxent Wildlife Research Center. All 16 sampling locations are marked. Sites 1–4 were sampled in April, sites 5–10 were sampled in May and sites 11–16 were sampled in June. Sites were selected randomly using a numbered grid map of PWRC and a random number generator.

although the eight powerline sites were located along only two different sets of transmission lines, that the sites were considerably separated in space, often with roads or fences separating them. No two sites sampled in the same sampling period were ever within sight of each other.

The probability of bees foraging, and thus of being sampled, varies considerably with weather conditions (Vicens and Bosch, 2000). Thus, in order to legitimately make faunal comparisons between sites, it was necessary to survey all sites within a consistently narrow window of time on a single day. This limited the number of sites we could reasonably visit during each sampling round, which is why the 16 sites were spread over three sampling periods. Collecting over three months, however, had the added benefit of enabling us to measure changes in the bee community over time, and to evaluate whether differences between sites were consistent over the season.

When we began this study, there were no widely accepted methods for standardized, quantitative sampling of bees. Most bees are nearly impossible to identify to species in the field, and so collections typically involve killing the bees for transport and examination in the laboratory. Perhaps the most common method for collecting bees is sweep netting, but this method is very time-intensive, and results likely vary significantly with experience level of the collector. Although we could not find published evidence for bees, studies on other arthropods have demonstrated significant differences in collector efficiency (Coddington et al., 1996; Dobyns, 1997) and in particular demonstrated that certain sampling methods such as sweep netting and hand collection can be more susceptible to collector bias than others such as pitfall trapping and litter extraction (Norris, 1999). One of the secondary goals of this study was to evaluate a potentially unbiased and time-efficient method of bee collecting that would be more amenable to cross-site comparisons. To this end, we made use of modified pan traps. Pan traps, while not impacted by observer bias, do not sample all bees in proportion to their occurrence as trappability varies with species. Pan traps do allow you to sample throughout the day, and to sample simultaneously in a wider area than would be possible with sweep netting. Our pan traps, hereafter referred to as “bee bowls”, consisted of brightly colored plastic party bowls, six inches in diameter, filled with water mixed with a small amount of unscented Ivory soap (following Kirk, 1984; Kearnes and Inouye, 1993; McIntyre and Hostetler, 2001). The soap breaks the surface tension, preventing insects that land on the surface from flying off again. Bees that are attracted to the bowls slip into the water and quickly drown. Four colors of bowl were used: light blue, dark blue, yellow and white. These colors are common in bee-pollinated flowers. The bowls at each site were arrayed in five sets of eight bowls each, for a total of 40 bowls. The eight bowls in each set were arranged in a circle of approximately 7 m radius, and the five sets were distributed along a linear transect with 25 m between sets (Fig. 2). The transects were placed in the center of each site, which meant directly under the transmission lines in the powerline strips and in the area maximizing the distance from bordering vegetation in the grassland sites. The bowls were cleared once a day for five consecutive days during each sampling period. Due to constraints on time and resources, bees were not separated based on bowl color, but instead were lumped by sampling location (i.e., all bees collected in each set of eight bowls were combined into one collection unit). Initially, some sweep net collecting was conducted at each site but yield was so comparatively low and effort comparatively high that we abandoned this method after the April collections. Interestingly, there was a high degree of overlap between the sweep net samples and bee bowl samples in April, thus we feel that eliminating this method did not likely affect our results significantly.

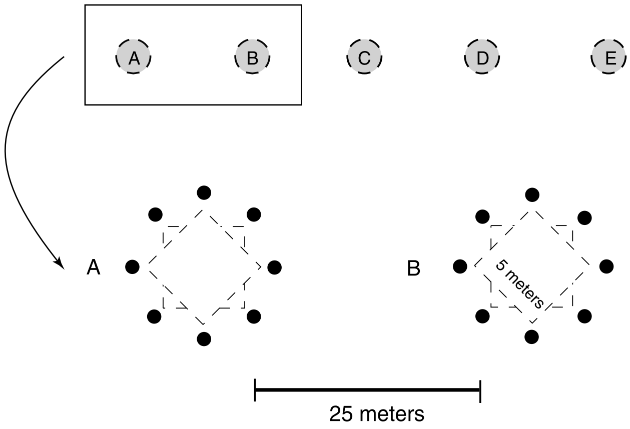

Fig. 2. Bee-bowl sampling scheme. A total of 40 bowls were placed at each site. Bowls were arranged in a linear transect of five sampling locations. Each sampling location had two each of the following colored bowls: dark blue, light blue, yellow and white.

Bees were kept in 70% ethanol until they were pinned. Bees were sorted to genus using Michener et al. (1994) and then to morphospecies. Approximately 75% of the morphospecies were then identified to species using Mitchell (1960, 1962) and other sources including museum collections. Although we are confident in all our genus identifications, there is likely some error in our species designations as none of the authors were officially trained in bee taxonomy. Still, the error was entirely blind (analysis did not begin until the identifications were finished), and the time cost of waiting for confirmation of all identifications by the relevant specialists in each group outweighed the desire for 100% accuracy.

2.3. Data analysis

Analysis of variance was used to look for differences in bee abundance and species richness between the site types. We performed a two-way crossed ANOVA with site type (powerline and grassland) and month (April, May, and June) as treatments. We performed an ordination (Canonical Correlation Analysis) to see if site types would fall out together based on the relative abundance of species collected. To further explore the differences between the two site types in terms of species identity, we considered the distribution of species across sites with respect to rarity, nesting preference and trophic level (parasitic vs. nonparasitic). Bees were classified with respect to nesting preference and trophic level based primarily on genus membership (Table 1). Finally, to assess the degree of species overlap between the site types, we calculated species turnover (following Russell et al., 1995) and Jaccard Similarity (following Magurran, 1988) for all pairwise comparisons within a sampling period. ANOVAs were performed using JMP software (3.2.1) and ordinations were performed using Mathematica (4.2), following the techniques in Legendre and Legendre (1998). Estimates of richness and diversity were calculated using EstimateS software (Colwell, 2000, version 6.0b1). Turnover and similarity indices were calculated using Matlab and EstimateS, respectively.

Morphospecies were included in all analyses unless indicated otherwise. However, in cases where there were male and female morphospecies within a genus collected at different sites and times, these data were eliminated because it was impossible to tell if the male and female morphospecies represented one or two species. In addition, two species in the genus *Ceratina* were combined into one, as there is no reliable method to distinguish females of this group.

Within each sampling period, we looked for reduced yields over time as an indication that we were depleting the local population. If depletion did occur, we could use this information to form a less biased estimate of the relative numbers of individuals living in the local area based on the shape of the depletion curve. Because the population was not closed and the sampling radii that the bowls collected from were undefinable, these values must be thought of as corrected relative abundance rather than density. Some evidence for depletion was seen, but there were reversals (Fig. 3). Reversals could be caused by changes in weather, the emergence of new species, or other stochastic events. Powerline sites exhibited more consistent declines in individuals caught across a 5-day sampling period than did grassland sites, particularly in April and June. Despite the lack of consistent declines, we presumed the curves provided a less biased portrait of the abundance of bees at these sites and used these numbers in addition to the raw

Table 1
Classification of genera by nesting preference and trophic level

Genus	Parasitic	Non-parasitic	Mostly cavity/stem	Mostly ground
Agapostemon		X		X
Andrena		X		X
Anthophora		X		X
Apis		X	X	
Augochlora		X		X
Augochlorella		X		X
Augochloropsis		X		X
Bombus		X	X	
Calliopsis		X		X
Ceratina		X	X (stem)	
Coelioxys	X		X	
Colletes		X		X
Halictus		X		X
Hoplitis		X	X (stem)	
Hylaeus		X	X (stem)	
Lasioglossum		X		X
Megachile		X	X	
Melissodes		X		X
Nomada	X			X
Osmia		X	X	
Panurginus		X		X
Sphecodes	X			X
Stelis	X		X (stem)	
Xyclopa		X	X	

Although these traits are not always generalizable to the genus level, in cases where genera were known to have a mixture of species we used the best available information to categorize them accurately based on species identities or the geographic location of our study (Jerome Rozen, Jr., personal communication; Michener, 2000).

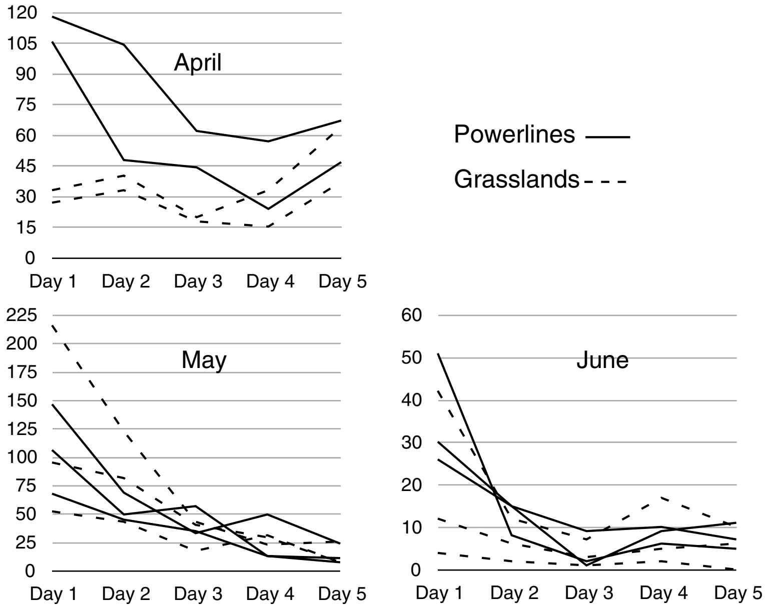

Fig. 3. Collection abundance over time for all sixteen sites plotted by sampling period. Bowls were cleared every 24 h.

abundance measurements to see if they produced different results.

Just as depletion curves can be used to correct for sampling bias, richness estimators can be used to predict the richness of a site based on a sample. Richness estimators can be useful when trying to compare areas sampled using different methods or with different intensity. However, results show that most richness estimators perform badly with small sample sizes (Melo et al., 2003; Cao et al., 2002; Walther and Morand, 1998; Chazdon et al., 1996). In addition, our sampling methods were standardized in space and time, so raw richness estimates should at least be comparable, even though they fall short of the true richness of the sites. Still, as a point of comparison with the analyses performed on the raw richness values, we decided to calculate richness estimates using those methods recommended in various reviews on the subject (Colwell and Coddington, 1994; Keating et al., 1998; Chazdon et al., 1996; Walther and Morand, 1998). We calculated Chao 1 and Chao 2, Bootstrap, first- and second-order Jacknife and Michaelis–Menton estimators using EstimateS (Colwell, 2000, version 6.0b1).

3. Results

A total of 2924 individuals were collected during the study and of those, 2887 individuals in 24 genera and 107 species were used in the analyses (Table 2).

Table 2
Summary of collections

	Grassland sites	Powerline sites	Total
Individuals	1282	1605	2887
Species	75	98	107
Genera	20	23	24

Powerline and grassland sites did differ significantly in the number of species collected, with powerline sites having more species on average than grassland sites (32.5 species versus 23.2 species; two-way ANOVA, $n = 16$, $F = 8.1463$, $p = 0.0171$). There was also a significant effect of month, with the number of species declining with month from April to June ($F = 10.9301$, $p = 0.003$). There was not a significant interaction between these two factors. We re-ran this analysis using the richness estimates calculated by the methods listed above. For the estimates that produced normally distributed data (Boostrap, first- and second-order Jackknife and Michaelis–Menton), the results did not differ appreciably from those based on raw richness (Table 3). Richness estimates based on Chao 1 and Chao 2 showed no treatment effect but this was due to a single richness estimate for Site 13 that was far outside the range of the other estimates (135 species vs. 28–50 for the others), and therefore suspect. With site 13 eliminated from the analysis, the results were again similar to those based on raw richness (Table 3). Because of the relative uncertainty of many of our species identifications, we decided to repeat the analyses using genus richness instead of species richness. Though the whole model fell short of significance ($p = 0.1$), the data showed a similar pattern with powerlines exhibiting higher genus richness than grassland sites (12.6 vs. 10, respectively; site type effect test: $F = 6.2863$, $p = 0.03$).

There was no difference found in the total number of individuals caught between grassland and powerline

Table 3
Results of two-way crossed ANOVA using the raw richness data and a variety of commonly used richness estimators

	n	F ratio (type)	Prob > F (type)	F ratio (month)	Prob > F (month)
Raw data	16	8.1463	0.0171	10.9301	0.003
Michaelis–Menton (mean)	16	10.3374	0.0093	7.3164	0.011
Bootstrap	16	8.9479	0.0135	10.5975	0.0034
First-order Jacknife	16	9.3149	0.0122	8.5937	0.0067
Second-order Jacknife	16	7.7162	0.0195	4.2814	0.0454
Chao 1	16		ns		ns
Chao 2	16		ns		ns
Chao 1[a] adjusted	15	12.2665	0.0067	8.6982	0.0079
Chao 2[a] adjusted	15	10.084	0.0113	3.0768	0.0959

No interactions were significant. Unlike the other richness estimators, data based on the Chao 1 and Chao 2 richness estimators showed no significant treatment effect. However, as stated in the text, this was likely due to a single richness estimate for site 13 that was far outside the range of the other estimates (135 species vs. a range of 28–50 for the others) and nowhere near the raw richness of 22 species measured at the site. Considering this estimate an outlier, we removed it from the analysis (=adjusted Chao 1 and Chao 2) and the resulting ANOVA produced a significant treatment effect.

[a] ANOVA was performed with the estimate for site 13 omitted from the analysis.

sites (two-way ANOVA; $F = 1.7871$, $p = 0.2109$), although this did vary significantly by month ($F = 11.2294$, $p = 0.0028$), with most individuals collected in May (Table 2). Again, there was no interaction. Results based on abundance estimates calculated from the depletion curves were essentially the same as those based on the raw numbers (type: $F = 1.316$, $p = 0.278$; month: $F = 13.5916$, $p = 0.0014$). Although in some of the grassland sites, the vegetation had grown up substantially since being mowed in April, the fact that the decrease in abundance of bees from May to June was consistent across site types, we felt the bulk of the decline was likely due to seasonal variation rather than change in vegetation structure (and hence bowl visability) in the grassland sites. It is possible that the large decline in bee abundance across sites was due to changes in regional floral resources. In the mid-Atlantic region of the Northeastern US, floral resources are most abundant in April and May, as many bulk flowering trees, understory plants and shrubs are in flower at the same time (Shetler and Wiser, 1987). As summer progresses in late May and early June, many of these resources disappear, as these plants put their energies into fruit production.

In April, floral resources in the grassland sites were sparse, consisting mostly of clover. In May and June, we observed only a few different species of flowering plants at the grassland sites, at fairly low abundance. In contrast, the scrub habitat of most powerline sites had consistently diverse and abundant flowering plants throughout the sampling season, with a moderate decrease in June. In addition, the grassland sites were structurally simple, offering fewer nest site choices. Although we did not quantify these differences, these observations led us to expect that grassland sites on their own could not support a rich fauna of bees (see Potts et al., 2003). We were surprised that the difference in richness between the site types, though significant, was not larger in magnitude. Therefore, we decided to examine more closely how the bee communities differed between the two site types. First, we looked at spatially rare species, defined as species collected at only one out of the sixteen sites. There were 28 species meeting this requirement and we wanted to know if they were randomly distributed with respect to site type. In fact, rare species were much more likely to be found in powerline sites than in grassland sites (21 vs. 7 out of 28, respectively). The consequence of this is that if you removed all the grassland sites and only collected in the powerline sites, you would lose 8% of the species, whereas in the reverse situation, you would lose 30% of the species collected. Results were similar with numerically rare species, defined as species with fewer than five individuals each. Of the 47 such species, 38 occurred in powerline sites compared to 18 in grassland sites (with nine species occurring in both).

The question remains, however, whether the bees collected at grassland sites are merely a random subset of bees collected at the powerline sites or if they do actually exhibit differences in community identity. To address this, we considered differences in behavioral diversity. First, we looked at nesting behavior, comparing the distribution of cavity- and ground-nesting bees. Of the 36 species and 735 individuals of cavity-nesting bees, 94% of the species and 66% of the individuals were collected in powerline sites compared with 75% of the species and 34% of the individuals collected in grassland sites. Results of chi-square tests on the number of individuals showed that there were significantly more cavity nesting bees in the powerline sites (expected values based on overall abundance in the two site types = 0.556:0.444; $X^2 = 32.7$, $p < 0.001$). We performed an ANOVA as described previously, but using just the cavity-nesting bees, and found there was a significant difference in richness between grassland sites and powerline sites and a marginally significant difference in abundance ($p = 0.04$ and 0.077, respectively). There were less pronounced dif-

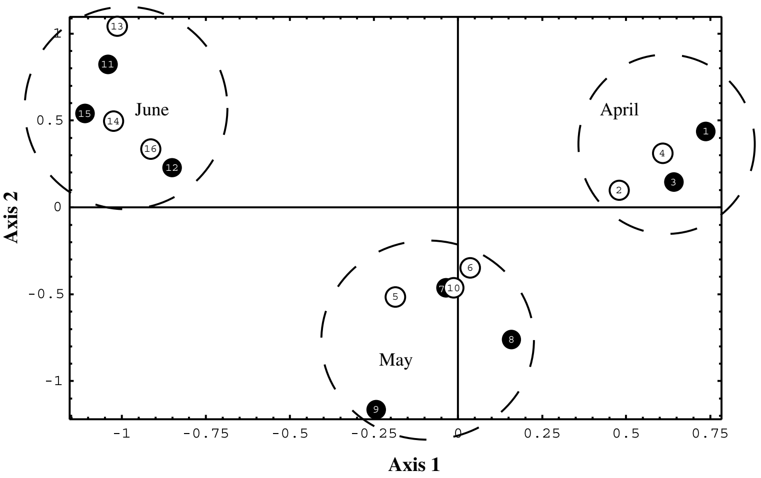

Fig. 4. Results of canonical correlation analysis based on the log-transformed abundance of species in each site (constrained by time along axis 1). The progressive change in species composition with time is statistically significant ($p < 0.0001$). Black circles are powerline sites and white circles are grassland sites.

ferences using only ground-nesting species; of 71 species and 2151 individuals, 90% of the species and 52% of the individuals were collected in powerline sites compared with 68% of the species and 48% of the individuals collected in grassland sites, though there were significantly more ground nesting individuals in the grassland sites than expected ($X^2 = 11.5$, $p = 0.001$). The ANOVA results indicated that although there was a significant difference in richness of ground nesting bees between powerline and grassland sites ($p = 0.024$), there was no difference in abundance ($p = 0.570$). Next, we looked at trophic level, comparing the distribution of parasitic and nonparasitic species of bee. Of the 16 species and 72 individuals of parasitic bees, 100% of the species and 72% of the individuals were collected in powerline sites, compared with 50% of species and 28% of individuals collected in grassland sites. χ^2 tests on the number of individuals showed that powerline sites have more parasitic bees than expected ($X^2 = 8.1$, $p = 0.004$) whereas nonparasitic species were distributed equally between the two site types ($X^2 = 0.227$, $p = 0.633$).

Certainly there are some differences in the groups of species collected at each of the site types, but do they represent distinct communities of bees? To answer this question, we performed correlation analysis on the log-transformed abundance (plus one) of species. In this unconstrained model, the primary axis was clearly related to time, with sites clustered according to month, indicating that sites sampled in the same month were more similar in species composition than sites sampled in different months and that the change in the community was progressive from April to June. There did not appear to be separation of powerline and grassland sites along any of the next few axes. A canonical correspondence analysis with randomization test, confirmed that month was a significant predictor of species composition ($p < 0.0001$), and subsequent, unconstrained axes still showed no evident partitioning of powerline and grassland sites (Fig. 4).

Turnover and Jaccard Similarity were calculated between samples from all sites surveyed in the same month. Results were highly variable, but on average, powerline sites had marginally lower turnover and higher similarity than grassland sites (0.4858 vs. 0.5496; 0.3486 vs. 0.314, respectively), though these differences are not statistically significant (based on a T test). The range of values for the within-grassland comparisons was much higher than for the within-powerline comparisons (range of 0.42 vs. 0.2 for turnover and 0.34 vs. 0.19 for Jaccard Similarity, respectively). As expected, cross comparisons (those comparing a grassland site with a powerline site) exhibited higher turnover (0.5628) and lower similarity (0.2881) on average than within-type comparisons. The 10 comparisons with the highest turnover and lowest similarity were always either grassland sites or cross-comparisons.

4. Discussion

The scrubby habitat of the powerline rights-of-way on the Patuxent Research Refuge appears to be home to a richer bee community, both in terms of raw richness and community composition, than the tall grass habitat of annually mowed fields. Powerline sites had more spatially rare species, more cavity nesting bees and more parasitic species than grassland sites. But based on the availability of floral resources and diversity of potential nesting sites observed in the two habitat types surveyed in this study, we had predicted a much larger and more consistent difference in observed richness than was apparent. There are two potentially relevant sampling issues that may have had an impact on our results. Both relate to our choice of sampling method, but in different ways.

First, our use of a passive collecting method instead of searching for nesting bees meant that we had no way of knowing if the bees we collected were residents, foragers, or both. Certainly, hand collecting at flowers would also not allow us to distinguish foragers from residents, but flowers are resources that are definitively present in the site. Our use of floral-colored bee bowls provides an added visual attractant to bees. As mentioned before, these were not closed systems and certainly many bee species are known to fly hundreds of meters or more in search of food and pollen. It is therefore likely that many bees caught were merely on a foraging trip and were attracted to the color of the bowls. On the other hand, the fact that there was some evidence for depletion after 5 days of collection indicates that neither are these systems entirely open. We believe there is evidence to suggest that these two site types differ in their degree of openness in a way that tempers the differences in the bee communities apparent in the samples. Looking at the depletion curves, it is obvious that particularly in April and June, grassland sites exhibit much less consistent declines in yield over time. This could be because the bowls in the powerline sites were sampling predominantly the local bee community whereas the bowls in grassland sites were sampling from a much larger area and hence a larger community of bees overall. Certainly the bowls themselves are more visible from a distance (or even from above) in the relatively simple architecture of the overgrown fields, compared with the sometimes dense scrub of the powerline habitats. It is likely that many bees traveled to the bowls from surrounding habitats, especially if there was a dearth of floral resources in the fields themselves. Other researchers who collect bees with bowls have noticed that sometimes yield is higher if bowls are placed where floral resources appear scarce, compared with areas with abundant flowers within the same landscape (J. Rozen, personal communication; N. Williams, personal communication). This phenomenon was also observed when researchers placed an artificial island of flowers in an otherwise florally limited area (Steffan-Dewenter et al., 2002) – the flowers received more visits by bees known to travel large distances to forage. It is interesting to note that six of the seven sites where *Apis mellifera* (the European honey bee) was collected in our study were grassland sites. This species is a cavity nester and is known to fly great distances when foraging.

The distance bees will travel away from their nests in search of food varies by species and appears to increase with size (Gathmann and Tscharntke, 2002). We would expect, therefore, to have fewer small bees in areas where nesting sites are limited as these bees are less likely to travel far from home. We compared the average size of bees between grassland sites and powerline sites to see if grasslands sites indeed had bigger bees on average, but found no significant differences between the site types. However, we did find that the smallest bee species (those under 5 mm in length) appeared to be restricted to the powerline sites, and if we include species up to and including 5 mm in length, 32 of 38 of these individuals were collected in powerline sites. Large species were equally abundant in the two site types.

Parasitic bees would be expected to spend less time foraging and more time near potential nesting sites than non parasitic bees because they do not provide for their own eggs, but rather make use of other bees' collected resources and nests. Indeed, we collected many more parasitic bees in the powerline sites than in the grassland sites. Cavity-nesting bees, too, were found to be more abundant in powerline sites than in grassland sites. Though cavity-nesting bees are likely to travel in search of food, we would still expect their numbers to be higher in close proximity to their nesting sites.

Finally, though the turnover and similarity indices were quite variable, the fact that powerline sites were on average more similar to each other than grassland sites is consistent with the idea that the character of the fauna collected in the grassland sites was more dependent on the character of the surrounding landscape. We did not take differences in bordering vegetation into account when we chose our sites. Some grassland sites were surround by woodlands, others by wetlands, others by cleared areas or some combination of the three. If bees were mostly coming to the grasslands to forage from the surrounding areas where they were nesting, then these differences in surrounding vegetation could result in quite different assemblages of bees found in the different grassland sites. Powerline sites, however, may represent more of a distinct habitat type and therefore would be more similar to each other irrespective of the surrounding vegetation. There was certainly more obvious variation in the nature of the onsite vegetation between powerline sites than between grassland sites (within a sampling period) and yet still the bee communities were more similar in powerline sites. The fact that the indices showed a much greater range of values for the grassland sites than for the powerline sites is also consistent with the idea that the surrounding landscape is having a greater influence on these sites; some grassland sites could be quite similar if they had similar surroundings, others quite different. Powerline sites, being less influenced by the bordering habitats should show more consistency in the indices, as they appear to do. Obviously, it is dangerous to infer too much from these indices, as they were highly variable. Much of this variation was likely due to spatial issues, which we did not factor in to the analysis. Though we did not quantify the distance between sites explicitly, we can say that those sites with the highest similarity and lowest turnover were not consistently in close proximity to one another.

We would argue that if there was a way to close these systems, the differences in richness and diversity of bees would be much greater between these two site types than was observed in this study. This is due to the greater diversity of nesting and floral resources available in the more complex habitat of the powerline scrub. It is clear that bees are using the grassland sites to forage, and certainly some bees are nesting there, but visitation to these sites was likely elevated by the presence of the bowls. We should add that the Patuxent Research Refuge is, overall, a haven for wild bees because it contains such a myriad of habitat types, especially of the early-successional variety. It is likely that a mowed field in a more developed landscape would yield vastly fewer bee species and a lower abundance of bees than what could be found anywhere on the Refuge due to a lack of source populations. It would be interesting to compare the bee communities of powerline rights-of-way managed for scrub vs. grassland in suburban or agricultural landscapes to see whether the same patterns emerge.

Despite the difficulties associated with interpreting data from bee bowls, due to the spatial issues described above, we do feel that in terms of overall efficiency, bee bowls are still the preferred method for this kind of study. They allow for easy sampling of large areas without the problem of sampler bias or the time necessary to carry out nest trap surveys. Though we expect that bee bowls sample a somewhat biased subset of the bee community (as any method will), our results indicate that the sub-sample is representative of the wider community. The ordination clearly shows a progressive change in the relative importance of bee species throughout the season, something that we know to be the case generally based on the life history of bees. The fact that the bee bowls picked up this change indicates that they were getting enough of a sample to show this progression despite random variation due to undersampling bias. If the communities were very undersampled, little or no significant progressive change would have been detected. In addition, as we are clearly asking comparative questions, any bias in the bee community sampled becomes irrelevant as long as the different sites were sampled in the same way.

5. Conclusions

Wild bees are a valuable natural resource whether you consider their economic value, their contribution to the ecosystem service of pollination in natural systems, or simply their contribution to the diversity of life on this planet. We have reason to believe that wild bee populations are being, or are soon likely to be, hit hard by changes in agricultural practices, land development, and the use of pesticides. It is critical that we do all we can to understand and provide for their needs, which include places to forage and places to nest. One small part of this endeavor should include making the most of any habitats that are already off-limits to further development. Already covering between 5 and 8 million acres of land in the continental US, and proportionally equivalent areas elsewhere in the world, powerline rights-of-way have the potential to be an invaluable resource. Data from this study indicate that rights-of-way managed for dense scrub can provide both floral and nesting resources for bees. It would be wise to do all we can to encourage power companies to abandon management practices that involve general herbicide application or periodic mowing of all vegetation, and instead to employ more widely the kind of management regime used on PWRC land. This could result in extensive corridors of habitat for bees and other early successional species in otherwise inhospitable environments. These habitats will also remain stable over time, as utility companies need to maintain them to keep tall vegetation from interfering with the overhead lines. This is particularly important in highly developed areas where source populations are not readily available to repopulate after mowing. Though it is naïve to think that any single management strategy will benefit all groups equally, this type of management would seem to provide a good starting point. From here, management could be modified to the needs of certain species or species groups on a local or regional basis. Whether we like it or not, powerline rights-of-way are a part of the modern landscape. Why not take the lemons and make lemonade?

Acknowledgments

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Appendix A

See Table 4.

Table 4
Species list and site totals

Species	1(PL)	2(G)	3(PL)	4(G)	5(G)	6(G)	7(PL)	8(PL)	9(PL)	10(G)	11(PL)	12(PL)	13(G)	14(G)	15(PL)	16(G)
Agapostemon texanus Cresson	1	0	1	1	3	0	10	1	1	0	1	0	0	0	1	0
Agapostemon virescens (Fabricius)	0	0	0	0	0	0	1	0	0	0	0	1	0	0	2	0
Andrena arabis Robertson	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena arabis Robertson	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena banksi Malloch	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena bradleyi Viereck	18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena carlini Cockerell	66	7	17	15	4	2	5	6	6	3	0	0	1	1	0	1
Andrena cressonii cressonii Robertson	6	0	1	1	0	0	0	0	1	3	1	1	4	1	0	0
Andrena erigeniae Robertson	5	30	106	4	25	205	152	122	40	338	0	0	0	0	0	0
Andrena imitatrix Cresson	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Andrena integra Smith	0	0	1	0	0	0	1	1	0	0	0	0	0	0	0	0
Andrena miranda Smith	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Andrena miserabilis Cresson	3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Andrena msp. A	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Andrena msp. B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Andrena msp. C	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Andrena msp. D	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena msp. E	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Andrena msp. F	0	2	0	0	0	0	1	0	0	0	1	12	7	3	3	2
Andrena msp. G	0	0	2	1	0	0	0	0	0	1	0	0	0	0	0	0
Andrena msp. H	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Andrena msp. I	5	12	14	8	3	15	5	13	3	12	0	1	0	0	0	0
Andrena personata Robertson	5	0	0	0	0	4	0	0	1	3	0	0	0	0	0	0
Andrena pruni Robertson	10	2	2	7	0	0	0	0	0	0	1	0	1	0	0	0
Andrena rugosa Robertson	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Andrena vicina Smith	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Andrena ziziae Robertson	0	0	0	3	0	0	0	0	0	0	0	0	1	0	0	0
Anthophora msp. A	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Apis mellifera Linnaeus	3	1	0	1	11	3	0	0	0	1	0	0	1	0	0	0
Augochlora pura pura (Say)	1	0	3	2	0	0	0	1	0	0	0	0	0	0	0	0
Augochlorella striata (Provancher)	15	2	14	24	16	1	1	0	1	11	1	0	0	0	2	2
Augochloropsis metallica fulgida (Smith)	0	0	0	4	0	1	0	0	0	0	1	0	0	0	0	0
Augochloropsis metallica metallica (Fabricius)	0	0	0	2	0	0	3	0	0	0	0	0	0	0	1	0
Bombus bimaculatus Cresson	0	1	1	0	0	1	0	0	0	1	0	1	0	0	0	1
Bombus fervidus (Fabricus)	1	3	6	7	3	4	3	1	0	0	0	2	1	0	0	0
Bombus impatiens Cresson	1	0	1	5	1	0	2	0	0	0	0	2	1	0	0	0
Bombus pensylvanicus Degeer	1	0	2	0	1	0	0	0	0	0	0	1	0	0	1	0
Bombus vagans Smith	1	0	0	1	0	0	0	1	0	0	0	0	0	0	1	0
Calliopsis andreniformis Smith	0	0	0	0	0	0	0	0	0	0	2	5	5	4	9	0
Ceratina calcarata/dupla	20	5	1	0	2	1	2	0	0	0	9	6	5	1	0	0
Ceratina strenua Smith	4	1	3	0	0	0	0	0	1	0	22	2	1	0	4	0
Coelioxys sayi Robertson	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Colletes thoracicus Smith	2	0	1	0	1	0	0	0	167	0	0	0	0	0	0	0
Colletes validus Cresson	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0
Halictus confusus confusus Smith	0	0	0	0	0	1	0	0	0	0	4	0	43	1	0	1
Halictus ligatus Say	0	0	0	0	20	0	7	0	0	2	2	1	0	0	0	0
Halictus rubicundus (Christ)	9	4	1	3	0	0	1	0	0	0	0	0	0	0	0	0

Hoplitis gleasoni Titus	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0
Hoplitis pilosifrons (Cresson)	0	0	0	0	1	0	4	1	10	0	0	0	0	0	1	0
Hoplitis producta Cresson	0	0	0	0	0	1	0	0	11	0	7	3	5	4	6	0
Hoplitis spoliata (Provancher)	0	0	0	0	0	2	0	2	24	0	0	3	0	0	2	0
Hylaeus affinis (Smith)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Lasioglossum acuminatum McGinley	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0
Lasioglossum bruneri (Crawford)	0	2	0	3	12	0	4	2	12	3	6	8	0	0	2	0
Lasioglossum coriaceum (Smith)	0	0	0	0	3	1	0	0	0	0	2	0	1	0	1	0
Lasioglossum cressonii (Robertson)	1	1	2	0	1	0	2	0	3	0	0	1	0	0	0	0
Lasioglossum forbesii (Robertson)	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
Lasioglossum msp. A	3	0	2	1	2	1	0	0	0	9	0	0	0	0	0	0
Lasioglossum msp. B	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Lasioglossum msp. C	2	0	4	1	7	0	0	0	0	18	1	1	0	4	1	0
Lasioglossum msp. D	2	0	0	1	0	0	0	0	1	3	0	0	0	1	0	0
Lasioglossum msp. G	1	0	0	0	3	0	1	0	2	11	1	0	1	1	0	0
Lasioglossum nelumbone (Robertson)	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Lasioglossum pectorale (Smith)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Lasioglossum pilosum pilosum (Smith)	2	0	0	2	0	0	0	0	0	0	0	0	0	0	13	0
Lasioglossum quebecense (Crawford)	12	0	9	1	0	0	0	0	0	0	0	0	0	0	0	0
Lasioglossum tegulare (Robertson)	2	0	0	0	0	0	0	0	2	0	0	2	0	0	2	0
Lasioglossum versatum (Robertson)	0	0	0	1	8	1	0	0	1	3	0	1	0	2	0	0
Lasioglossum vierecki (Crawford)	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0
Megachile brevis Say	0	0	0	0	0	0	2	0	0	1	0	0	1	3	0	0
Megachile exilis parexilis Mitchell	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Megachile mendica Cresson	0	0	0	0	0	0	0	0	0	0	1	1	1	1	5	0
Megachile msp. A	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0
Melissodes msp. A	0	0	0	0	0	1	2	1	1	3	0	0	0	0	1	0
Nomada cressonii cressonii Robertson	6	0	3	1	0	0	0	0	0	0	0	0	1	0	0	0
Nomada dentariae (Robertson)	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada lepida Cresson	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada luteoloides Robertson	3	0	1	0	1	1	1	1	0	1	0	1	0	0	0	0
Nomada maculata Cresson	2	0	2	2	0	0	0	2	0	0	0	1	0	0	0	0
Nomada msp. A	2	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0
Nomada msp. B	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Nomada msp. C	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada msp. D	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada msp. E	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Nomada perplexa Cresson	5	2	0	3	0	2	3	1	1	1	0	0	0	0	0	0
Nomada sayi Robertson	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0
Osmia albiventris Cresson	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Osmia atriventris Cresson	2	0	2	2	1	0	0	1	1	0	0	1	1	2	1	0
Osmia bucephala Cresson	5	3	11	2	0	1	1	1	0	0	2	1	1	0	0	0
Osmia coerulescens (Linnaeus)	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Osmia collinsiae Robertson	0	0	4	3	1	0	1	1	1	1	0	0	0	2	0	0
Osmia conjuncta Cresson	0	0	0	0	2	0	5	0	0	0	0	4	0	0	0	0
Osmia cornifrons (Radoszkowski)	9	1	2	5	0	0	0	0	0	0	0	0	0	0	0	0
Osmia distincta Cresson	12	1	10	7	0	0	2	0	0	0	0	0	0	0	0	0
Osmia georgica Cresson	4	1	2	4	0	0	0	0	0	0	0	0	0	0	0	0
Osmia inspergens Lovell & Cockerell	1	1	0	0	0	0	0	0	4	0	0	0	0	0	0	0

(*continued on next page*)

Table 4 (*continued*)

Species	1(PL)	2(G)	3(PL)	4(G)	5(G)	6(G)	7(PL)	8(PL)	9(PL)	10(G)	11(PL)	12(PL)	13(G)	14(G)	15(PL)	16(G)
Osmia lignaria Say	6	1	4	2	0	0	0	0	1	0	0	0	0	0	0	0
Osmia msp. A	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Osmia pumila Cresson	120	42	27	55	9	2	7	3	3	1	1	2	4	1	3	0
Osmia sandhouseae Mitchell	3	0	0	0	1	0	1	0	3	0	0	0	0	0	0	0
Osmia subfasciata Cresson	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Osmia taurus Smith	6	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panurginus potentillae (Crawford)	0	0	0	0	1	0	1	2	10	0	0	0	0	0	0	0
Sphecodes msp. A	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	2
Sphecodes msp. B	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stelis lateralis Cresson	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Xyclopa virginica virginica (Linnaeus)	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
Total richness	55	26	40	40	31	22	33	24	33	23	24	28	22	16	23	6
Total individuals	408	130	269	190	150	252	236	168	321	431	72	67	88	32	64	9

Sites one through four were sampled April 19th to April 23rd, sites five through ten were sampled May 7th to May 11th and sites 11 through 16 were sampled June 4th to June 8th. (G) designates grassland sites and (PL) designates powerline sites. Morpho-species are lettered within the appropriate genus. Two species in the genus Ceratina (*C. calcarata* Robertson and *C. dupla* Say) were combined into one since females could not be distinguished in the most recent revision (Daly, 1973).

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