Distribution and Habitat Use of the Rusty Patched Bumble Bee (*Bombus affinis*) and the Yellow-Banded Bumble Bee (*Bombus terricola*) in Ohio

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16. Abstract

Bumble bees contribute to Ohio's economic success and natural resources by pollinating wildflowers and crop plants. Two formerly widespread species have recently declined in Ohio: the Rusty-Patched Bumble Bee (*Bombus affinis*), designated as federally endangered in 2017, and the Yellow-Banded Bumble Bee (*Bombus terricola)*. Understanding their current distribution and habitat requirements is key to conservation and compliance with federal laws. We surveyed Ohio to assess the distribution of all bumble bee species and to determine whether the Rusty-Patched Bumble Bee and the Yellow-Banded Bumble Bee were present. We compiled information about the target species' historic and current distributions and habitat requirements, including foraging, nesting, and overwintering. We suggest best management practices for roadside habitats and detailed a non-lethal survey protocol to aid in monitoring for bumble bees of conservation concern. In > 400 h of surveys in 300 sites across Ohio, we recorded > 23,000 bumble bees representing 11 species, but did not locate any individuals of the two target species. We found that proximity to wooded habitat promotes bumble bee abundance. Wildflower plantings promote bumble bee diversity, but management practices, such as the timing and frequency of mowing, influence the value of that habitat for bumble bees. Some, but not all, of the native plant species commonly planted for pollinators in the Midwest attract bumble bees.

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November 2019

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Statement of problem

Bumble bees are important for pollination of wildflowers and crop plants. Therefore, they contribute to Ohio's economic success and natural resources. Recently, several bumble bee species have declined dramatically. In Ohio and much of the eastern USA, the Rusty Patched Bumble Bee (*Bombus affinis*) was once among the most common bumble bees, but since about 2000 it has declined in range by ~85% and in abundance by perhaps 95% (Symanski *et al*. 2016). In recognition of this abrupt turn toward extinction, the Rusty Patched Bumble Bee was recently proposed for listing on the federal endangered species list and was officially listed occurred March 21, 2017. Similarly, the Yellow Banded Bumble Bee (*Bombus terricola*) may also be declining, and is now being considered for federal listing (Defenders of Wildlife 2015).

The causes of these declines in range and abundance of formerly common bumble bees are not yet known with certainty, and probably involve several factors acting at once. The most likely causes include increasing pesticide use, habitat destruction, habitat fragmentation, climate change, and introduced diseases and pests (Goulson et al. 2015).

The listing of one bumble bee species, and the possibility that another species in our region may soon be listed as federally endangered, mean that transportation projects in Ohio may be affected by the need to preserve these bees and their habitat. Therefore, it would be wise to conduct a thorough survey of their past and current distribution in Ohio, describe their foraging, nesting, and overwintering habitat requirements, and determine where those habitats are located in Ohio. It would also be helpful to develop methods to recognize likely sites, and survey for their presence. While conducting these surveys, it makes sense to consider the distributions and habitat needs of all of Ohio's bumble bee species, some of which may also be in decline currently, or in the near future. This project aims to achieve those objectives.

Goals and Objectives

The goal of this research is to document the distributions and habitats of bumble bee species in Ohio, in particular *Bombus affinis* and *Bombus terricola,* which have experienced recent population declines and are, or may be in the future, classified as endangered by the United States Department of the Interior under the federal Endangered Species Act. In addition, the research aims to provide tools for assessing habitat for the presence, or likely absence, of the two target species. This information is being made available to the Ohio Department of Transportation for the purposes of planning and management of transportation projects in ways that minimize impact on these species and their habitat.

The specific objectives of the research are:

1) Generate a GIS layer of the current and historic distributions of the two bumble bee species based on the literature, available database entries, museum collections, and current state-wide field surveys.

2) Provide a description of the habitat of these two species in Ohio for foraging, nesting, and overwintering and determine correlates to habitat useful for its identification in Ohio.
3) Develop a list of best management practices for the habitat of the two target bee species based on the available scientific information and observations made during surveys that can be implemented by the Ohio Department of Transportation.
4) Develop a non-lethal protocol for surveys of the target species that includes collecting methods and assessing ecological and habitat correlates for the two species.

Summary of research methods and findings

Site selection and landscape classification

Survey sites consisted of fields, meadows, and other non-forested habitats with wildflowers that cover areas > 0.4 ha (1 ac) in total area. Sites were classified by habitat into the following categories: shrubby successional old field, recently abandoned crop or pasture lands, uncut hayfield, mowed lawn, urban vacant lot, urban flower patch (garden/landscaping/arboretum), roadside (highway medians and margins), planted wildflower meadows, and restored prairies.

We targeted sites with high quality foraging habitat for bees. These sites were easily accessed from roads or driveways and we had obtained land-owner permission to survey bees on each. These were a mix of public and private lands; some were highway margins.

For each site, we calculated the proportion of summer bee foraging habitat in the surrounding landscape as the total amount of grasslands and herbaceous vegetation, crop and pasture land, shrub land, and wetlands at specific distances of the sample site centroid, based on the National Land Cover Data set (Fry et al. 2011; analyzed in ArcGIS software, ESRI 2016). The National Land Cover Data set classifies land use into 90+ categories based on satellite imagery with 30 m (98.4 ft) resolution (list of categories available from: https://www.mrlc.gov/nlcd06_leg.php) and is updated every five years. We considered the surrounding landscape at three spatial scales: 1 km (0.62 mi), 2 km (1.24 mi), and 5 km (3.11 mi) radius buffer areas from the geographic site centroid. We chose these distances based on bumble bee foraging distances reported in the literature (Dramstad 1996; Osborne et al. 1999; Walther-Hellwig & Frankl 2000a, b; Wood et al. 2015b).

Bee survey protocols

For full surveys of bumble bee workers at sites of at least 0.4 ha (1 ac) in area, we conducted a timed bee survey during which bees were observed visiting flowers for 1.5 total "person hours", not including netting/handling time. At the start of the bee survey, we recorded the average temperature and wind speed using a Kestrel 2000 hand-held field weather meter (Kestrel Meters, Minneapolis, MN). Surveys were conducted in fair weather on days when temperatures were at least 18°C (64.4°F).

During the timed netting surveys, observers walked slowly, but steadily, through the best available wildflower habitat at the site and recorded all bee visits and the flower species on which they were observed. Bumble bees were tallied by species and by social caste (female worker, female queen, male) for each flower species. All other wild bees (including carpenter bees, sweat bees, mason bees, leafcutter bees, miner bees, long-horned bees, and others), were tallied and classified as "other". Honey bee workers (*Apis mellifera*) were also recorded.

Bumble bees were identified to species on the wing if possible, or were netted and transferred into a clear temporary holding vial, identified using a field guide, photographed if necessary to confirm the species identity, and promptly released on site. Thus, this was a non-lethal survey, and should have minimal effect on bee populations. To avoid re-counting the same individuals, observers did point counts on a patch of flowers, then moved to another patch within the habitat. Blank data sheets used are provided (**Appendix A**). For bee surveys we used tally marks in the rows of the data table as we observed individuals of each species/caste. Plant species on which bees were observed were indicated in the column headers. Site location, date, time, and local environmental data were recorded on the data sheet header.

Plant survey protocols

Bee abundance and diversity are highly dependent on the flower community on a given site and day. Therefore, upon each site visit observers conducted a plant survey along four 25 m x 1 m (82 x 3.28 ft) transects in order to inventory the available resources for bees in a given place and time. The four transects were placed within the site in a way that best represented the flower community in the area where we focused our timed bee observations.

In each transect, we counted and recorded the number of flower units of each species currently in bloom. Flower units were defined as "bee walkable clusters" (Saville 1993), or the number of flowers a bee could visit by walking before it would have to fly to the next cluster. What constituted one flower unit was defined separately for each plant species based on floral morphology and on our observations of bee foraging behavior. For example, bees foraging on milkweed (*Asclepias* spp.) inflorescences land and then walk between individual flowers in a cluster, so each cluster was considered one unit from a bee's perspective. Similarly, although each clover (*Trifolium* spp.) head is composed of many individual flowers, the whole inflorescence was counted as one unit because bees gather nectar and pollen from many small flowers each time they land on a clover head. Observers sketched a diagram of the "unit" to ensure repeatability and consistency.

All flowers were identified in the field using Newcomb's Wildflower Guide (Newcomb 1989) or by collecting and pressing vouchers and consulting keys and experts.

Habitat descriptions

Site geographic coordinates were recorded in the field as the location of a parking or access point, for ease of finding the site upon return visits. Upon completion of the bee and flower surveys, observers evaluated the presence/absence and quantity of each of five key habitat features known to influence nesting resources for bees: rocks (> 0.25 m in diameter), bare soil (0.5 m diameter patches), clump- or tussock-forming grasses, standing twigs or pithy stems, and dead decaying logs. Each of these nesting resources was scored as either absent or present in low (1-5 units), medium (5-20), or high abundance (>20) across the survey site. Observers also categorized the variation in the height of flowering vegetation as 0.1 – 0.5 m in height, 0.5 – 1.0 m, or > 1.5 m (**Appendix A**)

For sites located within areas classified as "high priority" or "low priority" by the USFWS, i.e., those where relatively recent historical records of *B. affinis* exist (https://www.fws.gov/midwest/endangered/insects/rpbb/rpbbmap.html), we also completed the USFWS habitat assessment data sheets (https://www.fws.gov/midwest/endangered/insects/rpbb/pdf/HabitatAssessmentFormGuideByXercesForRPBB.pdf).

Bumble bee queen survey protocols

The colony is the reproductive unit of bumble bees and is initiated by overwintered queens in the spring. Conservation of bumble bees, therefore, must include consideration of habitat used by queens in spring to establish nests. To improve our understanding of the nesting ecology and habitat requirements of bumble bees, we surveyed for queens on mild weather spring days when the air temperature was at least 15.5°C (mean temperature at time of survey 25.50°C ± 3.95) with little wind, between the hours of 9:00 and 19:00. Survey locations included state and municipal parks, as well as private properties, and were at least 3 km apart.

We documented the species distributions, habitat associations, and phenology of bumble bee queens in teams of 1 – 5 observers. At each site we searched all available habitat types at each site for a total of 60 person-minutes, paying special attention to areas with dense vegetative or woody debris (*e.g.* grass clumps, leaf litter, or fallen logs) or complex microtopography (*e.g.* stream banks, buttressing tree bases, road embankments). We recorded the start and end time of survey, the temperature, cloud conditions (sunny, partly sunny, or cloudy), average ground wind speed (mph), and the amount of time spent searching each habitat type.

Bumble bee queens were identified to species on the wing or net-collected and photographed for later identification using the Williams et al. (2014) guide to bumble bees of North America, then re-released on site. Observers minimized double counting queens by moving to a new patch of flowers or potential nesting habitat after a queen was observed.

At the time of observation, each queens' behavior was categorized as either foraging, nest site searching, or flying. In addition, it was noted whether each queen was carrying pollen in her corbiculae, as an indicator that she had already founded a nest. For foraging queens, we recorded the species of plant on which each bee was observed. For nest site searching queens, we collected additional information on their behavior and microhabitat use. The amount of time in minutes an observer spent watching each queen was noted, and her behavior was classified as either flying low over the ground in a back and forth sweeping motion or disappearing down holes or in crevices and re-appearing some time later. The habitat type in which each queen was observed was categorized as: forest, woodland, forest or woodland edge, grassland/meadow, maintained area (mowed lawn or flower bed). We also noted the presence or absence of the following microhabitat features in the immediate area where she was searching for a nest site: leaf litter, herbaceous litter, grass clumps or tussocks, fallen logs or large woody debris, rock piles, mounds of bare soil, moss, stream or river, lake or pond, trees in full bloom, shrubs in full bloom, and herbaceous plants in full bloom. Nest-site searching queens were observed for between 30 seconds – 10 minutes, depending on the amount of time the bee could be followed. The majority of nest-searching queens were observed for 30 seconds – 1 minute. The cumulative growing degree day of each survey was obtained using the location and sample date of each survey with an online calculator (Ohio State University 2015).

For about three-quarters of the nest site searching queens (n = 405) we obtained individual GPS coordinates for their exact locations. For those queens, we extracted the land use in a 1 km area around each queen's location from the most recent National Land Cover Database (NLCD, Homer et al. 2015) using ArcGIS 10.6.1 (ESRI 2018). The NLCD database classifies land use with 30 m resolution into 90+ categories for the conterminous US. Land cover categories in the original dataset were simplified into several broad categories based on the quality of bumble bee nesting and flower resources they offer: forest, shrubland, herbaceous and pasture land, row crop agriculture, and low, medium, and high intensity developed areas, and other.

As observers searched for queens, they kept a list of flowering plant species currently in bloom that would be potential food sources for bumble bees. Dominant species that were flowering abundantly and most likely to attract bumble bees were noted.

All data analyses were conducted in R (R Development Core Team 2017).

Survey results

Summer worker bee surveys

We conducted 318 individual surveys in 225 sites across 66 of Ohio's 88 counties (**Figure 1**) in June – August of 2017 and 2018. We prioritized sites in two areas of the state (Lucas Co and Franklin Co) where the US Fish and Wildlife Service had previously designated "High" and "Low" potential zones where the rusty-patched bumble bee was likely to be seen and were able to survey 10 locations within these priority areas (United States Fish and Wildlife Service 2017).

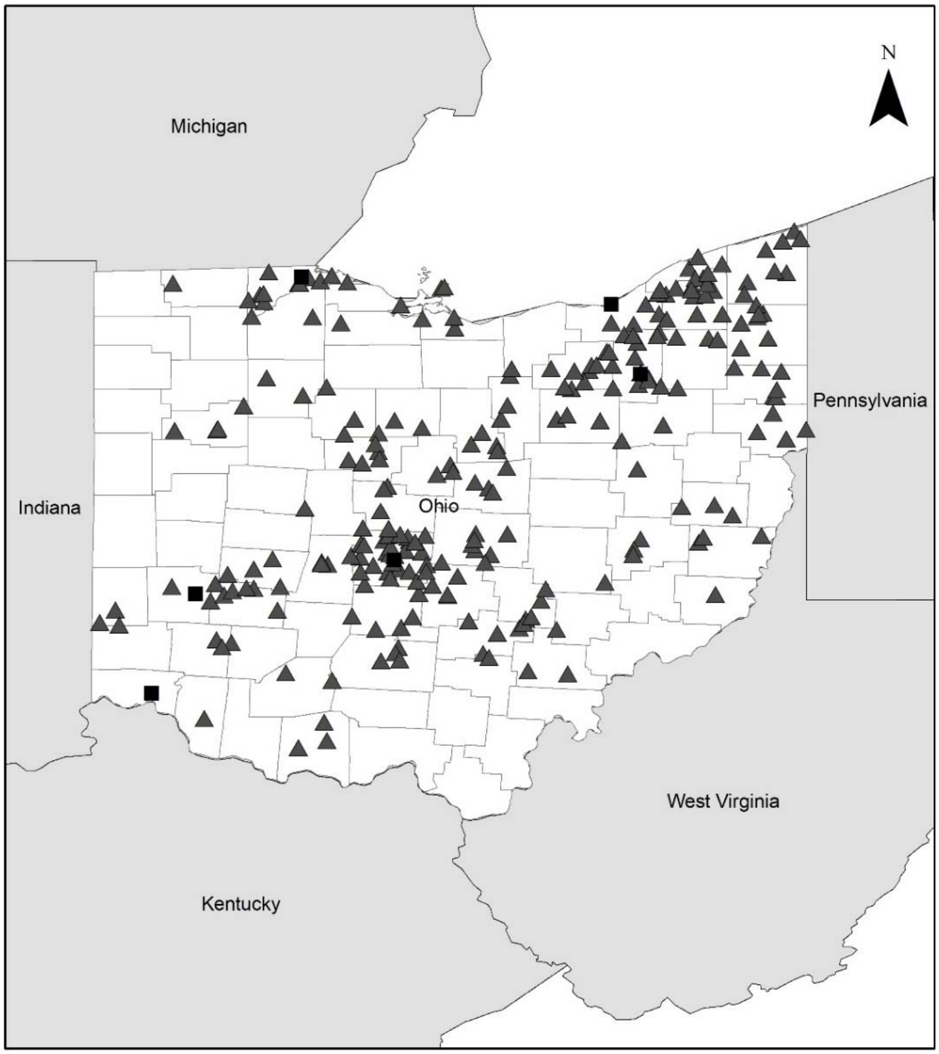


Figure 1. *Summer survey sites for bumble bee workers in 2017 and 2018. Squares are cities with population > 100,000 and triangles are survey sites.*

Most sites were public parks or preserves (~60%), and the rest were privately managed parks, private residences, or roadsides managed by various agencies (**Figure 2**). Of the 225 sites, the planted meadow was the most common habitat type, but we also surveyed as many roadsides, natural fields, shrubby, and urban patch as possible with the constraint that there be abundant floral resources (**Figure 3**).

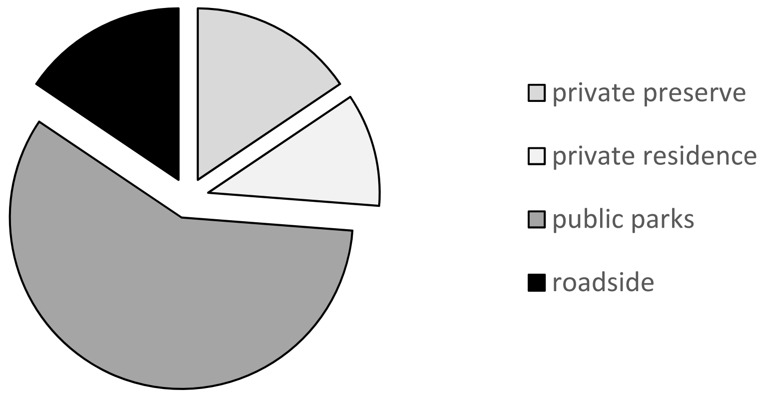


Figure 2. *Proportion of the 225 summer bee survey sites categorized into the four management classes. Some of these sites were sampled in both years. Some were included in spring queen surveys.*

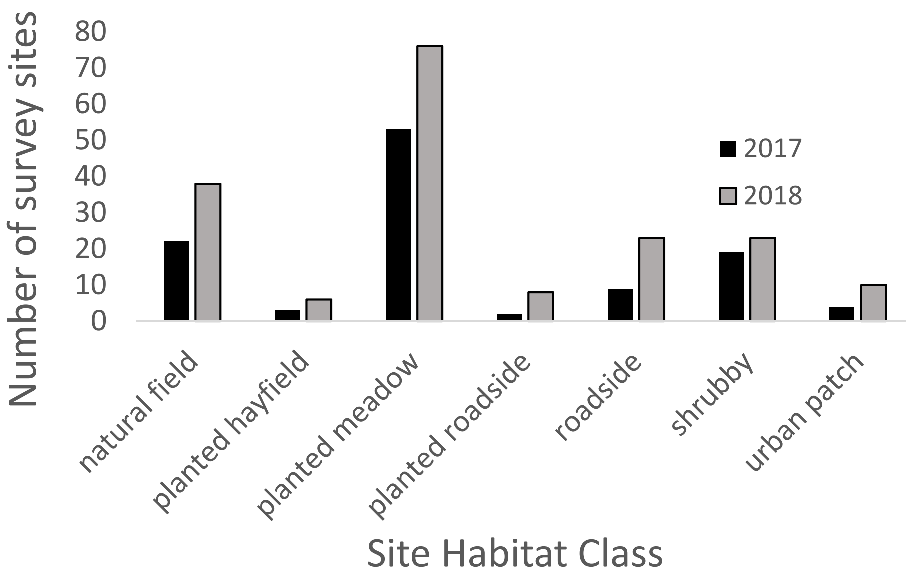


Figure 3. *Site habitat classifications for the summer bee survey sites from 2017 and 2018.*

During 90 min surveys over two years, we documented 23,748 individual bumble bees of 11 species (**Table 1**). **We did not find either of the target species, *Bombus affinis* or *B. terricola*.** Unidentified bumble bees comprised 0.3% of bees observed, so it is unlikely we missed these two species in our survey. Three species strongly dominated Ohio's bumble bee communities, *Bombus impatiens* (49%), *Bombus griseocollis* (29%), and *Bombus bimaculatus* (14%) (**Figure 4**), cumulatively accounting for over 92% of the bees we saw. In our analyses, we considered the remaining seven species "rare" species.

Table 1. Total sampling effort for Ohio bumble bee survey 2017 – 2018. Totals for 2018 includes the spring queen survey and the summer worker survey. Some sites were sampled more than once. Bumble bee species were: B. impatiens, B. griseocollis, B. bimaculatus, B. fervidus, B. vagans, B. perplexus, B. auricomus, B. pensylvanicus, B. citrinus *(social parasite, queens and males only),* B. borealis *(1 worker in 2018),* B. sandersoni *(1 queen in 2018).*

	Surveys	Ohio counties	# bumble bees	# species
2017 total	130	43	10,078	9
2018 total	229	57	15,052	11
2018 spring queen surveys	116	28	1,382	10
2018 summer worker surveys	188	54	13,670	11
Grand total	277	66	25,130	11

Although we did not find the target species during these surveys, we conducted statistical analyses on the other species to determine what kinds of factors influence the abundance of all bumble bees, bumble bee richness (number of species), and the abundance of the "rare" species observed during 90 min surveys. These analyses are helpful to identify habitat characteristics that may promote the target species because published information and historic distributions suggest that they have occurred in similar habitats in the past. We used generalized linear models with the following explanatory factors: abundance and richness, habitat class, habitat management (planted or not), growing degree day (GDD), latitude, cloud cover, temperature, and year. We used model selection procedures in R and determined the best fit model using a comparison of AIC values (Johnson and Omland 2004).

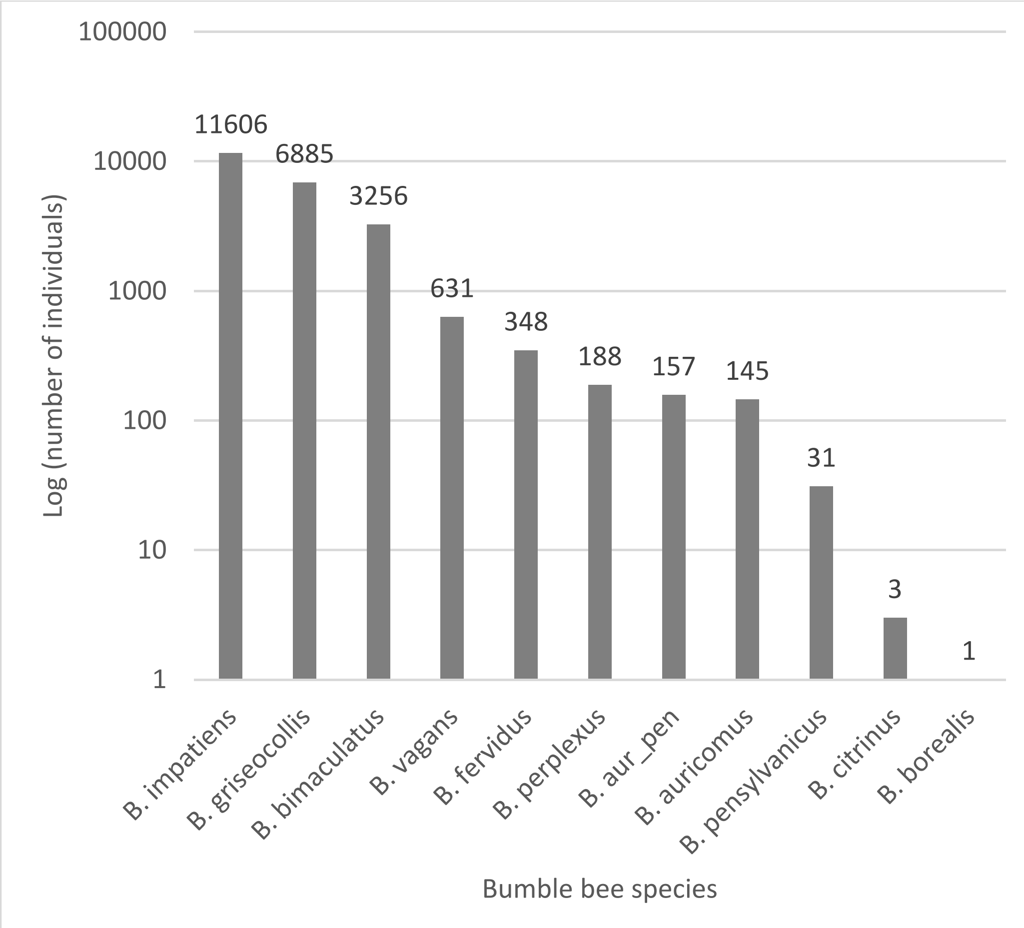


Figure 4. *Counts of bumble bee species observed during 90 min surveys in 2017 and 2018.* Bombus auricomus *and* B. pensylvanicus *(*B. aur_pen*) were combined in 2017 and in part in 2018 because of lack of consistency in species identification.*

The number of bumble bee individuals observed was best predicted by a model that included positive effects of floral abundance, and number of flower species (**Table 2**). The number of bumble bee species observed was best predicted by models that included positive effects of number of flower species. The number of "rare" bumble bees observed (total number of bumble bees minus the top three most abundant species) was best predicted by a model that included the number of flower species. Observed bumble bee abundance was positively associated with GDD and latitude, while bumble bee richness was negatively associated with GDD and positively associated with latitude.

From these analyses, we conclude that abundant floral resources, especially when occurring in diverse mixtures, attract foraging bumble bees and therefore are key components of suitable habitat for bumble bees. Although not a new discovery, it confirms management approaches that enhance floral resources are defensible strategies for supporting bumble bees.

Table 2. *Best fit generalized linear models of bumble bee abundance, richness and the abundance of "rare" species (total abundance minus the three most abundant species). Shown are parameter estimates for each of the factors included in the best fit model. Flower abundance is the total number of flowers, Flower richness is the number of flower species, GDD is the growing degree day on which the survey was conducted. * indicates that year was included in all best fit models, but does not have a parameter estimate because it was a qualitative variable. For each response variable, the best fit model had the lowest AICc value.*

Response variable	Intercept	Flower abundance	Flower richness	GDD	Latitude	Year
Bumble bee abundance	81.37	10.50	8.30	10.92	14.26	*
Bumble bee richness	3.84		0.19	-0.36	0.15	*
"rare" Bumble bee abundance	4.73		0.95	-0.74	0.76	*

Bumble bees are generalist foragers that visit a wide variety of flowers for nectar and pollen. We ranked all flower species on which more than 100 bumble bees were observed (Appendix B). To identify preferred floral resources, it is important to account for the influence of flower abundance on bumble bee visitation. To that end, we regressed the total number of bees found on each flower species on the summed flower abundance for that species. We highlighted those species that were visited more than expected based on their abundance (**Figure 5**). These "magnet" flowers are some of the most important species that support bumble bees. The top ranked species are Bee balm (*Monarda fistulosa*), Common milkweed (*Asclepias syriaca*), Teasel (*Dipsaucus* sp.), Red clover (*Trifolium pratense*), and Compass plant (*Siplhium* spp.). Bee balm, milkweed, and compass plant are native species and are excellent choices for enhanced pollinator habitat. The milkweed has the added benefit of supporting monarch butterfly larvae, though it lacks a usable pollen resource for bees. Based on research from neighboring Michigan, declining bumble bee species tended to have later phenology and narrower diets, peaking in summer when floral resources may be limiting, especially flowers in fields, such as clovers (*Trifolium* spp.) (Wood et al. 2019)

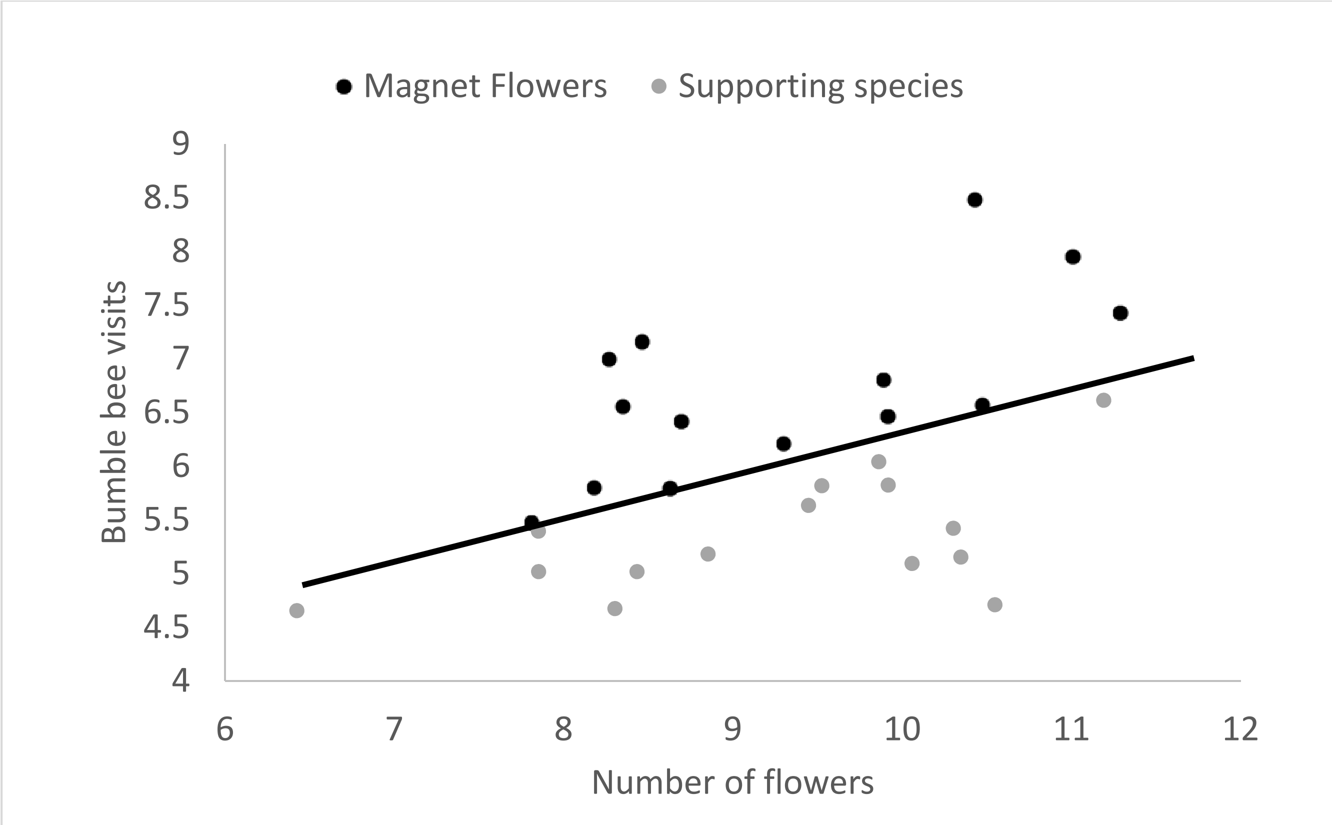


Figure 5. *The number of bumble bee visits to flower species as a function of the flower abundance for each of 32 plant species on which > 100 bumble bees were observed, summed across all observation periods. Both independent and response variable are expressed as natural logs. The line is a linear fit (R^2 = 0.203, n = 32, p < 0.01). The points in black we termed "magnet flowers" because they represent species that were visited more than predicted based on their abundance. The points in gray are "supporting species" that are visited but not more, and sometimes less, than expected based on the flower abundance. See text for a list of the top ranked magnet species.*

From the surveys of worker bees, we did not find strong differences between the habitat categories for bee abundance or richness. Bumble bees have foraging distances of > 1000 m (0.62 mi) and large numbers of workers a colony. Therefore, they should be able to access floral resources over a wide area that may cross habitat boundaries. The early part of the life cycle, during which lone queens are searching for suitable nest sites and foraging for floral resources, is likely a more vulnerable life stage that will show greater habitat associations. Below we report on the results of the queen survey conducted in the spring of 2018.

Spring queen bumble bee survey

We conducted non-lethal surveys of foraging and nest searching queen bumble bees at 116 sites in 28 counties in Ohio, USA from May 11 – June 8, 2018 (**Figure 6, Table 1).** Researchers observed 451 nest seekers and 555 foraging queens of 9 different species (**Figure 7**). We did not find either of the two target species, *Bombus affinis* and *Bombus terricola*, but we did find one species that had not been reported previously as a queen in Ohio, *B. sandersoni*.

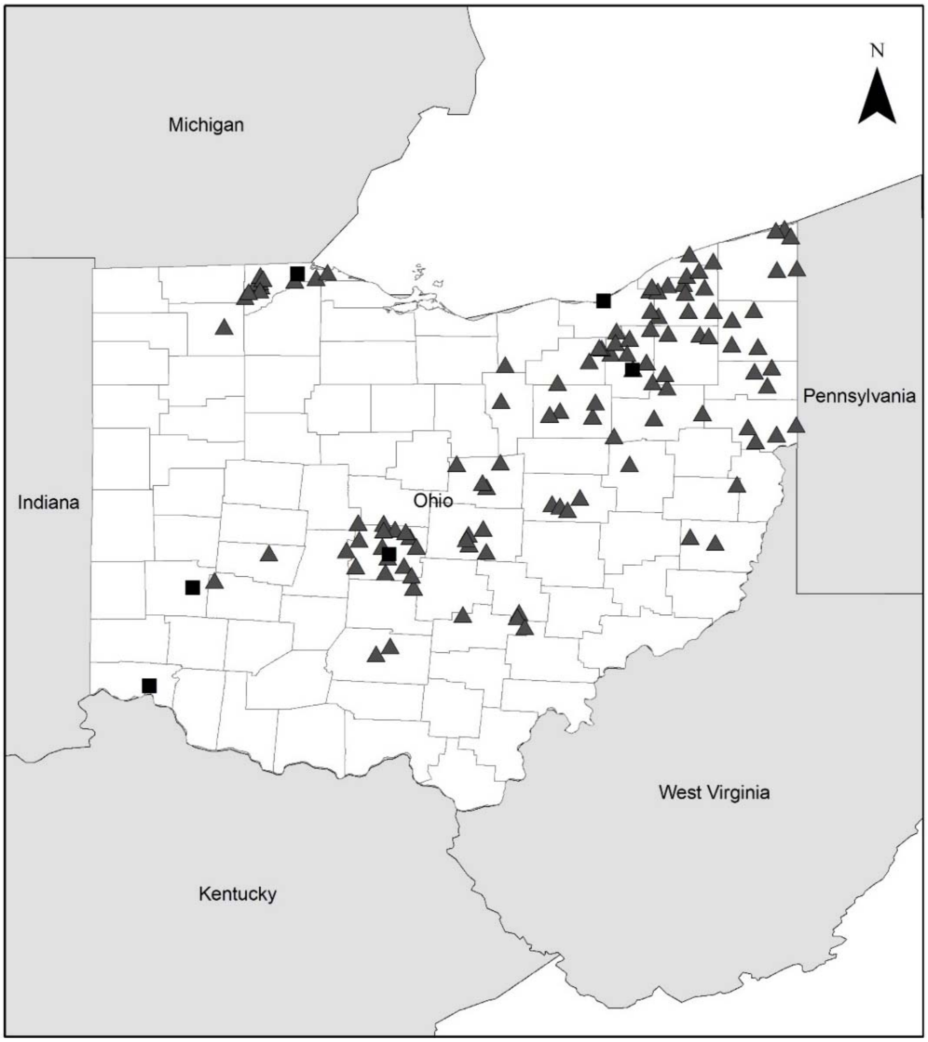


Figure 6. *Ohio survey sites for bumble bee queens in 2018. Squares are Ohio cities with > 100,000 residents. Triangles are survey sites.*

Spring queen activity began in mid-April and peaked in mid-May, although nest seekers were observed into late June. Nest seeking queens favored woody and woody-field edge habitats over open habitats (**Figure 8**). This pattern was largely driven by the dominant species, *B. impatiens.* Queens of *B. auricomus* and *B. fervidus* were only found searching for nest sites in open areas (meadows, roadsides, and maintained flower beds/lawns). The parasitic species, *Bombus citrinus*, on the other hand, was only observed seeking host nests in wooded areas. Several of the less common queen species in this dataset (*B. vagans, B. perplexus, B. citrinus, and B. auricomus*) were observed nest seeking in natural habitats, but not in heavily maintained areas (lawns, gardens, and flower beds). In accordance, queen abundance and diversity increased with the proportion of forest in the surrounding landscape (**Figure 9**). The proportion of row crops and urban areas negatively influenced queen diversity and the number of nest seekers, respectively.

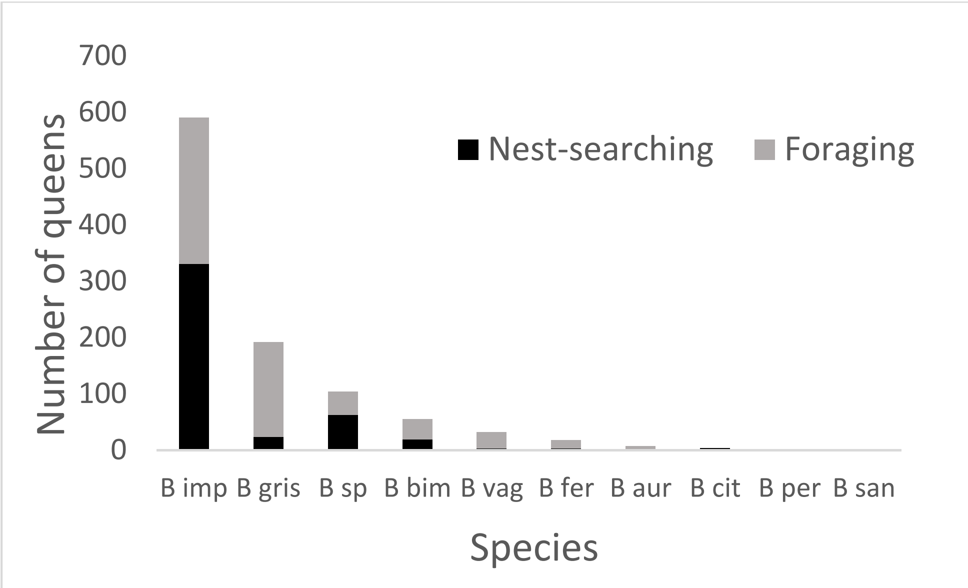


Figure 7. *Counts of foraging and nest-seeking bumble bee queens observed during the spring bumble bee surveys. Abbreviated species names represent the following species:* B. impatiens, B. griseocollis, Bombus (*undetermined species),* B. bimaculatus, B. vagans, B. fervidus, B. auricomus, B. citrinus, B. perplexus, B. sandersoni

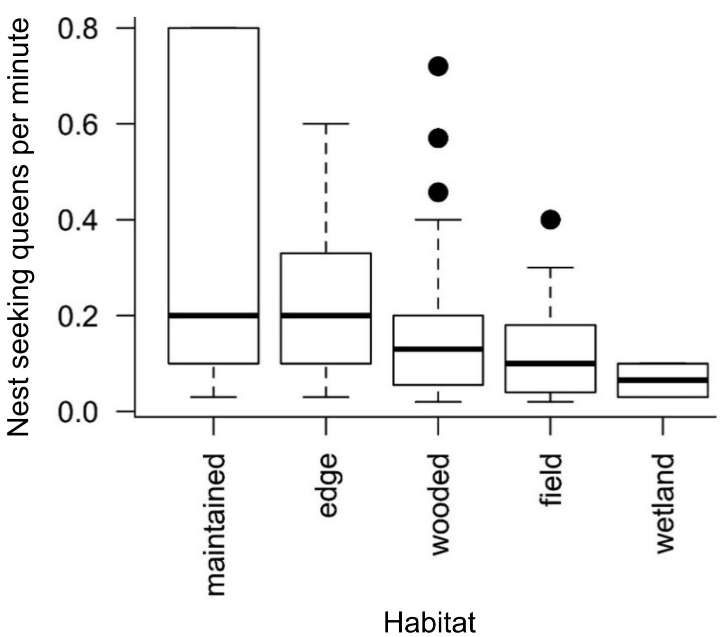


Figure 8. *Habitat associations of nest seeking queens. Queen abundance is given as the number of nest seeking queens observed per minute by habitat type in timed surveys (n = 78 sites at which queens were observed nest seeking). The dark line = median queens per minute. Box boundaries = upper and lower 25% quartiles. Kruskal-Wallace test of differences between habitat types indicated significant differences in number of queens per minute (H = 14.91, df = 4, P < 0.01). Wooded and edge habitats had more bees per minute than other habitats.*

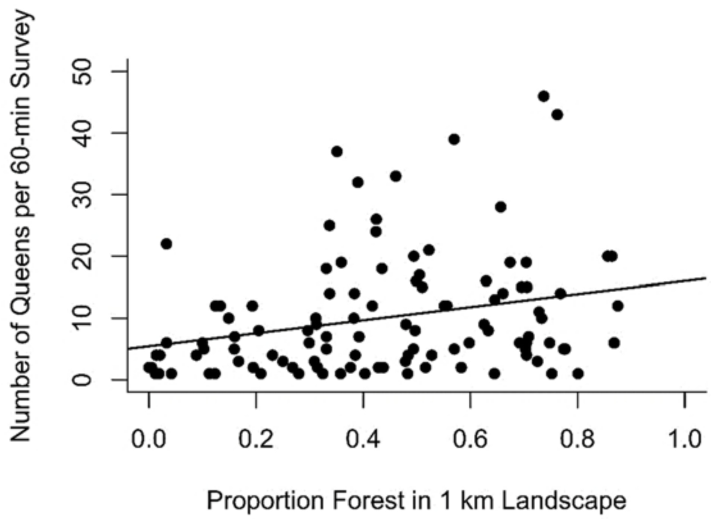


***Figure 9**. Influence of the proportion of forest in the landscape on queen abundance in timed field surveys. The proportion of forest was calculated in a 1 km buffer area surrounding each site, for n = 108 time queen surveys. The correlation between proportion of forest and queen abundance is shown as a black line (r = 0.27, t = 2.84, df = 106, P = 0.01).*

Nest-seeking queens focused on particular features of the vegetation and microhabitat. Most were found searching in the leaf litter and around woody debris, such as large fallen logs (**Figures 10, 11**). Many queens were found nest-searching around the buttresses at the base of large trees within forested areas. The species found nest-searching in open habitat, *B. fervidus* and *B. auricomus*, mainly focused on grass tussocks and herbaceous litter. Bumble bees opportunistically use existing hollows for nesting, including rodent burrows and other natural hollows, but also crevices in manmade structures. Interspersed wooded and open habitats are particularly favorable for bumble bee nest establishment, though open grasslands and prairies may favor some species of concern, such as *B. pensylvanicus*. Management strategies that promote adequate nesting habitat should consider fostering diverse vegetation and microhabitat heterogeneity whenever possible.

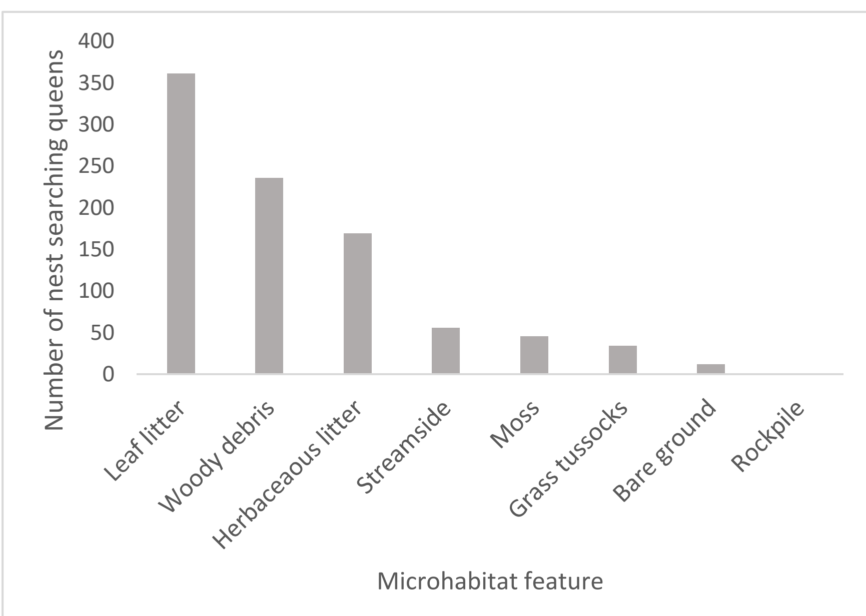


Figure 10. *Microhabitat features that were within 2 m of the 451 nest searching queens. Some queens had multiple features in proximity*.

Fifty species of flowering plants were used by 555 foraging queens. Key food plants included both native and non-natives(*), herbaceous plants, shrubs, and small trees: lupine (*Lupinus perennis*) (138 queens), apples (*Malus* spp.)(62), dandelion (*Taraxacum officinale*)* (48), honey suckle (*Lonicera* spp.)* (40), dead nettle (*Lamium purpureum*)* (39), ground ivy (*Glechoma hederacea*)* (29), *Trifolium pratense** (26), *Mertensia virginica* (25), and privet (*Ligustrum vulgare*)* (25).

Figure 11. *Sample photos of foraging and nest-seeking queen bumble bees. Left:* Bombus impatiens *queen nest-searching in leaf litter. Photo credit D. Reiser, volunteer. Above:* B. griseocollis *queen visiting Virginia blue bells in a forest understory at Dawes Arboretum, Newark, OH. Photo credit K-L. J. Hung*.

An important outcome of the queen survey is a better understanding of the phenology of the species in Ohio. There was a strong pattern of queen abundance with GDD (**Figure 12**); queen activity in Ohio ranged from 11 April - 29 June with the peak activity mid-May. Providing floral resources during this period when queens are solely responsible for foraging to initiate brood production is likely to have a large impact on the success of bumble bee colonies and bee abundance later in the season. Species that have later phenologies, such as *B. fervidus, B. auricomus,* and *B. pensylvanicus* will require adequate floral resources during their nest establishment phase, late May – June in most of Ohio.

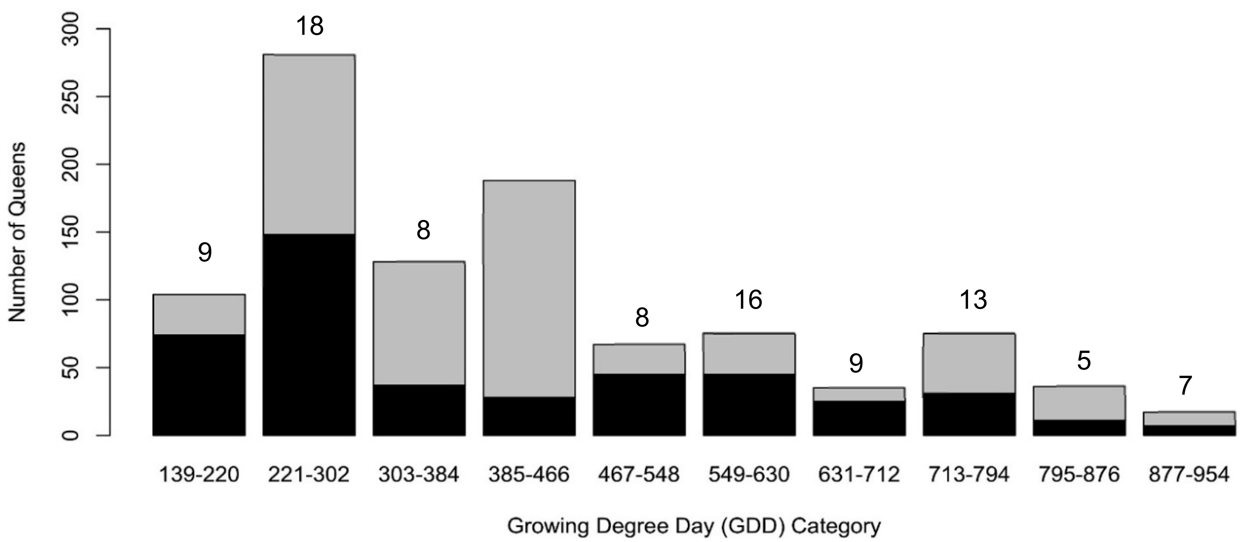


Figure 12. *Phenology of nest searching and foraging queen from 116 timed field surveys from 11 May — 8 June, 2018. Growing degree day, calculated for each survey location and date, is divided into 10 equal-interval bins and the number of surveys conducted during each bin are shown above the bars. Black bars = number of nest seeking queens. Gray bars = number of foraging queens.*

Managing habitat

Nesting habitat requirements

Like all bumble bees, *B. affinis* and *B. terricola* require habitats to support three main life cycle phases: foraging, nesting, and overwintering. For a location to be suitable for bumble bees, all three of those requirements must be met. However, because bees are quite mobile, the specific sites providing each of those components can be separated from the others by a mile or more. For example, foraging habitat might be 2 km or more away from nesting or overwintering habitat. For this reason, one should look at habitat availability at a 1-10 km landscape scale (Woodgate et al. 2016).

Our research and literature surveys point to three critical dimensions of bumble bee habitat that should form the pillars of habitat management for promoting bumble bees. This approach will support colony establishment, as well as growth and help ensure successful production of reproductive castes (queens and males).

1. **Microhabitat heterogeneity within a mosaic of wooded and open habitats to promote nest sites.**
2. **Abundant floral resources in the April and May.**
3. **Abundant floral resources available in June through August, focusing on those species that tend to be favored by foraging bees.**

Bombus affinis is typically associated with grassland-type habitats. These could include fields, pastures, restored or unrestored meadows, or agricultural lands reverting to a natural state. In a catalog of bumble bees of Ontario, Canada, Colla and Dumesh (2010) also include wooded areas and urban parks and gardens in their list the habitats used by the rusty-patched bumble bee, in addition to open fields. Little specific information was found about the nesting requirements of *Bombus terricola.* **Therefore, we suggest that a mixture of wooded habitats (which offer spring forage and sheltered locations for queens to overwinter and found nests) and non-agricultural fields (which offer abundant summertime flowers) would most likely support bumble bees of many species, including these**.

Rusty-Patched Bumble Bees typically nest one to four feet underground in abandoned rodent burrows or other cavities and excavate a tunnel entrance (Frison 1917; Plath 1934; Macfarlane 1974; Macfarlane et al. 1994). Because of their depth underground, Plath (1934) says that this species seems to prefer old chipmunk over mouse burrows. However, taking into account the nesting habits of other bumble bees, Rusty-Patched Bumble Bees may also occasionally select nest sites at ground level in grass tussocks, around human structures or objects, or in other places sheltered from the weather. Franklin (1912) reported finding a nest in the early 1900's on the surface of the ground in a mowed field in Vermont.

Overwintering Habitat for Queens

Overwintering queens require loose, well-drained soil in a place that will be undisturbed by humans or other animals and sheltered from the cold from September (or October) through March (or April), and from premature warming in March – April (Frison 1923; Alford 1969).

They do not hibernate in their natal nest, likely because of issues with diseases and scavengers/predators. In the petition to list the rusty-patched bumble bee as a federally endangered species, Jepsen et al. (2013) explain that "Although little is known about the overwintering habits of rusty patched bumble bee queens, queens of other species frequently dig a few centimeters into soft, disturbed soil and form an oval shaped chamber in which she will spend the duration of the winter." Kearns and Thomson (2001) say that queens burrow 5 - 15 cm underground to overwinter. Goulson (2010) suggests that compost piles in gardens or the loosely heaped soil of mole hills may provide suitable places for queens to overwinter. Dense mats of decomposing leaf litter in wooded areas may also offer protection for overwintering queens. Hobbs (1964, 1965a, b, 1966a, b, 1967, 1968) observed mated bumble bee queens digging 1 – 4 inches deep into sphagnum moss or loose soil (especially moist sandy soil) on slopes to hibernate. Atypically, Frison (1923) found an overwintering queen of another species (*B. variabilis*) in a crevice in a tree stump, and mentions another that was found elsewhere in a corn stalk. In Ohio, overwintering queens of a highly successful and widespread bumble bee species (*B. impatiens*) have also been observed aggregating under a fallen log in the forest (*personal observation*).

Best Management Practices

Nationwide, there are >10 million acres of roadside right-of-way land (Federal Highway Administration 2017). Recently renewed efforts to enhance roadside habitat for native flora and fauna, outlined its goals for Integrated Vegetation Management and Wildflower programs as "assuring water quality, improving erosion control, increasing wildflower habitat, reducing mowing and spraying, enhancing natural beauty, and protecting natural heritage." (Federal Highway Administration 2018a).

State-level efforts to restore roadside pollinator habitat have increased in recent years following a 2014 Presidential Memorandum that established a national Pollinator Health Task Force and called for involvement of many government agencies (The White House Office of the Press Secretary 2014). Many state Departments of Transportation, including Ohio, have now adopted Integrated Vegetation Management or begun other roadside habitat restoration programs. In addition to benefiting wildlife, pollinator-friendly roadside management can also help reduce the cost of roadside maintenance. Indiana and Texas DOT's have reported decreased costs through changes in mowing and herbicide spraying maintenance plans. Although state DOT's often hire out habitat restoration plantings to private contractors, it is important for agency vegetation managers to be informed on the process so that they can ensure the contractors have done their job effectively. To that end, the FHWA has compiled an e-handbook for state roadside vegetation managers tasked with planting roadsides with native species (FHWA 2018b). They have also worked with the Xerces Society for Invertebrate Conservation to review and collate the available literature on roadside pollinator habitat restoration (Hopwood et al. 2015). Here we give an overview of the major steps in restoring roadside pollinator habitat, and make special recommendations for bumble bee-friendly wildflowers to include in seed mixes in Ohio restoration projects. The Best Management

Practices Fact sheet summarizes recommendations for promoting good bumble bee habitat considering forage, nesting, and life cycle phenology.

In Ohio, we have > 250,000 lane miles of highways (Federal Highway Administration 2017). If roadsides can be transformed into favorable foraging habitat for wild bees (our most important pollinators of crops and wildflowers in temperature North America), they could increase the amount of foraging habitat in highly-disturbed landscapes. If they offer adequate flowers throughout the summer, roadsides could also act as habitat corridors and help to offset the negative effects of habitat fragmentation by connecting larger patches of bee habitat**. Practices that promote other pollinators will also likely benefit the endangered Rusty-Patched Bumble Bee, *Bombus affinis* and the Yellow-Banded Bumble Bee, *Bombus terricola*.**

Bumble bees are larger bodied than most wild bees and forage for flowers in multiple adjacent habitats. They also have a preference for the flowers of weedy herbaceous legumes that grow abundantly on roadsides – clovers (*Trifolium pratense*, *T. repens*), vetches (*Vicia* spp.), crown vetch (*Securigera varia*), birdsfoot trefoil (*Lotus corniculatus*), and sweetclover (*Melilotus*). Therefore, bumble bees are likely to use and benefit from roadside pollinator plantings. **We found significantly more bumble bee species were found in surveys of roadsides planted with native wildflowers (12) than in unenhanced roadsides (32). In addition, bumble bees were observed foraging on a wider variety of plants species in restored compared to unrestored roadside flower patches.**

In general, the goals for establishing or enhancing roadside pollinator habitat are that the project must be aesthetically pleasing, provide habitat for wildlife (in this case, flowering plants that increase the pollen and nectar available for wild bees), resist invasion by woody plants and other nearby aggressively-growing non-native plants, and be economically established and maintained (Center for Environmental Excellence by AASHTO, 2018). Midwestern roadside habitat managed for pollinators has most often incorporated native prairie species adapted to growing in open habitats and tolerant of seasonal mowing (Hopwood et al. 2015).

Major steps in creating or enhancing roadside pollinator habitat

1) **Conduct an initial survey of the planned project area considering** (modified from Hopwood et al. 2015)**:**
   a) **size** of the area to be planted (crucial for ordering the right amount of seed and other materials and getting project cost estimates, larger plots will also be more resistant to invasion by surrounding non-native plants)
   b) **soil conditions** (wet / dry, compaction, soil type and texture)
   c) **existing vegetation** (Is it primarily woody or herbaceous?, Are there aggressively growing non-natives that could later crowd-out and compromise your native plants?)
   d) **slope** of the land (to determine the most effective planting method and what equipment is needed).
2) **Design a restoration wildflower mix**.

Before the initiation of a restoration project, check to see if there are federal funds available for implementing pollinator-friendly vegetation management plans. Funding for state vegetation managers for the control of noxious weeds and promotion of native plants was authorized under the 2005 SAFETEA-LU act, and is codified in Title 23 of the U.S. Code, Section 329 (Federal Highway Administration 2018c).

a) Choose flowering plant species with a variety of bloom times, shapes, colors, and heights to attract a variety of native pollinators and to offer flowers across the growing season (ideally from May – September). Wildflower species that grow vigorously in various soil conditions, persist in restoration plantings, and are highly-visited by bumble bees make them good candidates for restoration of roadside bee habitat. Examples of such species include *Agastache foeniculum*, *Asclepias incarnata*, *Asclepias syriaca**, *Asclepias tuberosa*, *Aster nove-angliae*, *Aster umbellatus*, *Astragalus canadensis*, *Chamaechrista fasciculata*, *Echinacea purpurea**, *Eryngium yuccifolium*, *Euthamia graminifolia*, *Heliopsis helianthoides*, *Helianthus* spp.*, *Liatris* spp.*, *Monarda fistulosa**, *Penstemon digitalis**, *Pycnanthemum tenuifolium**, *Ratibida pinnata**, *Rudbeckia hirta*, *Silphium* spp., *Solidago* spp., *Trifolium pratense***, *Verbena hastata*, *Veronicastrum virginicum**, *Zizea aurea* (**Appendix C**). Plants that were particularly highly-visited by bumble bees in our 2017 - 2018 surveys are marked with an *****.

b) If the soil conditions are wet, consider adding species tolerant of wet habitats such as *Physostegia virginiana**, *Eutrochium purpureum**, and *Eupatorium perfoliatum*.

c) Choose native grasses to provide nesting habitat for several species of bumble bees that nest in grass clumps. Recommended species are: *Bouteloua curtipendula*, *Elymus canadensis*, *Schizachyrium scoparium*, and *Sorghastrum nutans*.

d) Well-established regional suppliers of native plant seed include the Ohio Prairie Nursery (Hiram, OH; www.ohioprairienursery.com), Ernst Seed (Meadville, PA; www.ernstseed.com, and Prairie Moon Nursery (Winona, MN; https://www.prairiemoon.com/). These companies offer seeds of regional plant ecotypes, which should establish well and have higher survival. Most native plant suppliers sell pre-made seed mixes designed for specific groups of wildlife, in addition to custom made-to-order mixes. For example, the Ohio Prairie Nursery offers a “Bee Friendly” mix and a “Birds and Butterflies” mix. Ernst Seed offers a “Mesic to Dry Native Pollinator” mix. For a comparison of popular pollinator-friendly seed mixes from three supplies and which species are included in each see **Appendix C.** It is recommended to order seed well in advance of desired seeding date to ensure availability of the seed.

e) To customize the seed mix for attracting bumble bees, we recommend reducing the proportion of *Rudbeckia* and *Gaillardia* in the seed mix compared to ready-made commercially-available pollinator-friendly mixes. Those plants are a source of pollen for small-bodied bees that visit shallow flowers (e.g., sweat bees in the genera *Halictus* and *Lasioglossum*) but are not frequently visited by bumble bees, which have longer tongues and higher resource requirements. For practical purposes, *Rudbeckia* grows vigorously and persists well (which can help maintain favorable public opinion about roadside plantings), but can be aggressive and may exclude more desirable species eventually. *Coreopsis* spp. bloom in the first years of restoration plantings, but seem to get out-competed within several years (personal observation), so they are likely not worth the investment for restoration plantings in Ohio.

3) **Choose a seeding rate.**
The Federal Highway Administration suggests a seeding rate of 2 – 5 lbs / acre for wildflowers and 7 – 10 lbs / acre of native grasses (Federal Highway Adninistration 2018b). Note that this seeding rate is *much* lower than that suggested by native plant seed growers, because native wildflower seed is expensive. Seed growers recommend 10 – 20 lbs per acre for most restoration seed mixes (**Appendix C**).

4) **Prepare the site for planting.**
First, remove existing vegetation, typically by applying herbicides to the area you will plant. After one week, re-assess and re-treat if needed. Next, till the ground to plow under the dead weedy vegetation.

5) **Plant with native vegetation.**
For best results, plant in the early spring, winter, or in the fall. The most-commonly used method of planting is to broadcast seed, but other options include hydroseeding or drill-seeding. Consider planting seedlings as plugs or bareroot seedlings, if the budget allows or in certain situations. For example, you might want to planting seedlings if the project is in a high-traffic area that is highly-visible to the public, or on a steep slope where vegetation needed to be established quickly to control erosion. An argument for planting some seedlings in addition to seed, is that seedlings will establish and bloom sooner than plantings from seed (which will take several years until you see flowers blooming). At the time of planting, it will improve the performance of native wildflowers if the soil is inoculated with mycorrhizal fungi, which form beneficial associations with the roots of herbaceous plant that help them uptake additional phosphorus from the soil.

6) **Follow up: continued care, maintenance, and monitoring.**
   a) Immediately after planting if it is a dry spring and there is no precipitation in the first few weeks after planting, you will need to water the project area until the seeds sprout and begin to establish. If you plant plug or bare root seedlings, you will also need to water them.
   b) **Avoid mowing or applying herbicides to roadside bee habitat during the spring in places where there are abundant flowers.** According to a survey of management practices by state DOTs, some states have already begun formal or informal reduced mowing programs to benefit pollinators and other wildlife, including Ohio, which reportedly mows roadsides in the fall (Hopwood et al. 2016). This practice should favor bumble bee establishment and colony growth. April –June is a sensitive time of year when overwintered bumble bee queens emerge and establish new

nests. Killing even one queen removes potentially hundreds of workers later in the season. Likewise, killing workers from the first brood in late May to mid-June, when nests are still small, may greatly diminish the colony's chance of reproducing. Bumble bee diversity peaks for the season in late June and early July, and by September the majority of bumble bees are of one species – *Bombus impatiens*. If additional mowing were needed, say to manage invasive species, it could be done in late June or early July (after the spring bloom) and again in September or October after the majority of bee queens have entered hibernacula for the winter. These recommendations will avoid directly killing adult bees and entire nests of bumble bees (of species that nest at the surface of the ground in grassland habitats). It will also encourage bees to forage within the habitat patch instead of seeking alternative forage. Leaving the habitat patch could cause higher mortality rates of adult bees due to collision with vehicles when they leave roadside patches.

   c) **Avoid pesticides wherever possible.** Herbicides can reduce floral resources available to bees and pesticides can kill or sicken bees. Spot-spray only to kill undesirable plants (ex: non-native thistle, teasel, bush honeysuckle, or autumn olive). Blanket spraying kills non-target vegetation, and eliminates or contaminates flowers for bees.

7) **Conduct an annual flower survey** in late June – early August to take stock of which planted species are flowering and which have disappeared. Consider whether or not back-seeding or inter-seeding is needed to maintain the area as pollinator habitat.

8) **Monitor bumble bees** at sites that are actively managed for bumble bees. This step is critical to assessing the success of the management plan. We provided a protocol for non-lethal sampling of bumble bees that is appropriate for roadsides and other sites (**Appendix A**).

Literature review

We searched scientific databases, locating all articles with bumble bee in the title and using those articles to locate additional publications, both periodicals and books. The information gleaned from these has been incorporated into this report and appendices, as well as the fact sheets.

Of the 237 scientific articles spanning more than a century (1912 - 2018), 72% were published in the last two decades. The most common topics included declines and distributions, flower resource use, habitat associations, nesting biology and reproduction (**Figure 13**). We have also provided full references and details of the 237 references (**Appendix D**).

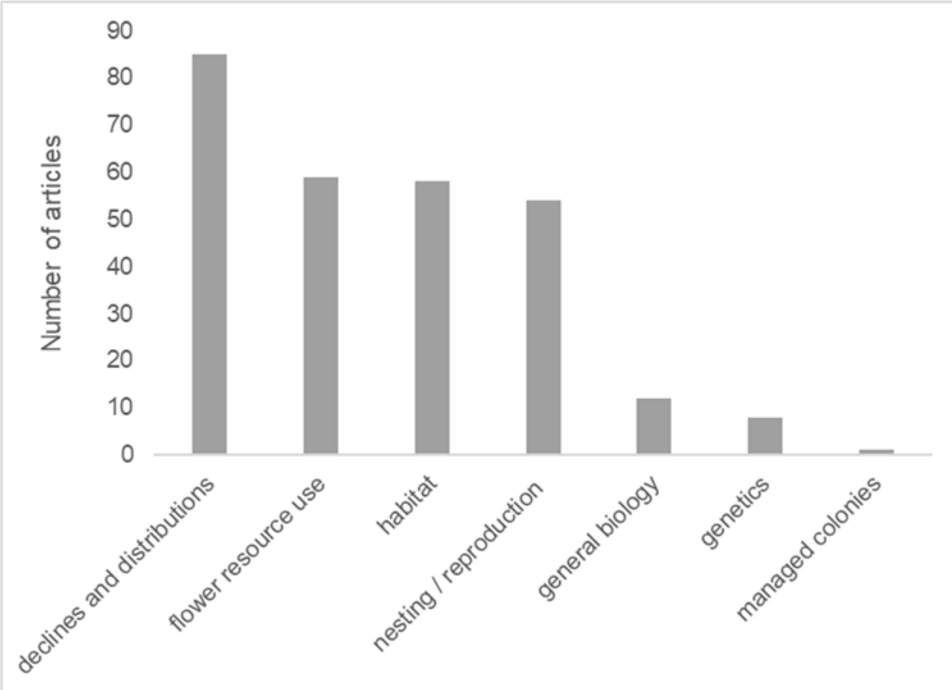
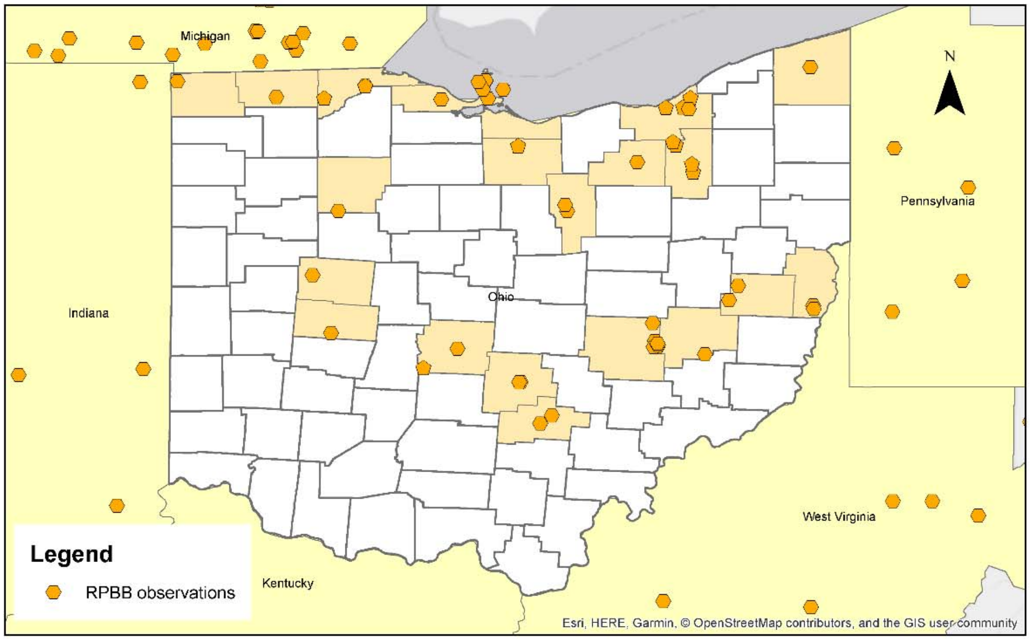


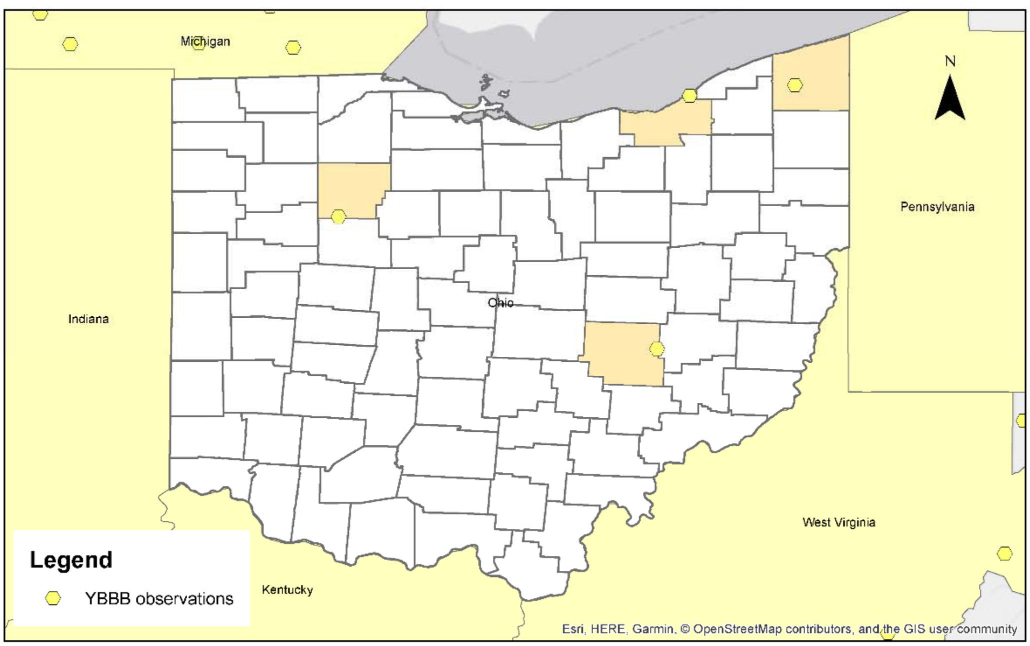
Figure 13. *The distribution of scientific articles on bumble bees across research topics. Details of these papers are provided in Appendix D.*

GIS layer of historic range of target species

Maps of the historic range of the target species show confirmed observations in Ohio based on ArcGIS layers compiled by our team using all available databases and literature (**Figure 14**).

The ArcGIS layers of rusty-patched (*Bombus affinis*) and yellow-banded bumble bee (*B. terricola*) historic ranges in eastern North America are shapefiles composed of points where those two species have been observed or collected in the recent recorded past (ca. 1900 - 2018). The layer was created using the geographic coordinate system NAD 1983 (2011 version). Our primary sources of information were: (1) data downloaded from Bumble Bee Watch (Https://bumblebeewatch.org), national digital citizen science platform; (2) specimens housed at the Ohio State University C.A. Triplehorn Insect Collection (Https://insects.osu.edu); and (3) data downloaded from the Global Biodiversity Information Facility (Https://gbif.org), the published dataset of bumble bee records in Cameron et al. (2011).





Coordinate System: GCS North American 1983
Datum: North American 1983
Units: Degree

Figure 14. *Historic sightings of the Rusty-patched Bumble Bee (Top) and the Yellow-banded bumble bee (Bottom) in Ohio and surrounding sites. See text for sources.* ***There were no sightings of these species in 2017-2018.***

We made a special effort to locate additional Ohio observations of these two species that were overlooked in the large national datasets above: (1) data downloaded from iNaturalist, Ohio Bee Atlas project, digital citizen science platform with bee identifications from photos crowd-sourced by experts across the region; (2) reported observations of *B. affinis* in two master's theses from Dr. Randall Mitchell's lab at the University of Akron (Prusnek 1999; Bernhardt 2000); (3) the USFWS revealed the location of two recent *B. affinis* observations in Franklin County (Karen Halberg, USFWS biologist, *personal communication,* 2018). One was verifiable (2005, Graessle Rd, Franklin County) but the other was not (2000, Blendon Woods, Franklin County); (4) examination of specimens housed at the Cleveland Museum of Natural History.

The historic observations of the Rusty-Patched Bumble Bee indicate that it occurred in at least 21 Counties of Ohio ranging from the northeastern corner to the northwestern corner and extending into central Ohio (**Figure 14).** This species was observed in urban and rural areas, including some heavily agricultural areas. It appears to be extinct from all of these areas now, with the last few sightings in Columbus and Toledo, relatively urban areas. The Yellow-Banded Bumble Bee, was observed in only four counties, though geographically dispersed. It may have been widespread, but uncommon at best. This species is also apparently missing from Ohio according to our surveys. Other published studies that suggest that its range has contracted and is currently concentrated in northern and high altitude regions (Colla and Packer 2008, Cameron et al. 2011, Jacobson et al. 2017)

Conclusions and deliverables:

Despite > 500 hours of observation at > 300 sites, and species-level identification of > 23,000 bumble bees over two years, we were unable to detect *Bombus affinis*. In museum collections from the 19th and 20th century *B. affinis* made up about 15% of *Bombus* specimens, indicating that it was once quite common. These results suggest that it is at the least much less abundant than in the past, and is likely extirpated from the state. We were also unable to detect *Bombus terricola*, which has never been common in Ohio. Nevertheless, we gained a good understanding of the abundance and distribution of Ohio's other bumble bee species, some of which are in decline in parts of the Midwest and may become targets for conservation in the future. This information can be used to plan bumble bee, and more generally, pollinator conservation efforts by the Ohio DOT and other agencies.

Objective 1 for this study was to generate GIS layers of the current and historic distributions of the two bumble bee species. These are summarized above and in **Figure 14** and the data are provided in separate files.

Objective 2 was to provide a description of the habitat of *Bombus affinis* and *Bombus terricola*. We based the descriptions and recommendations above on our literature survey (**Appendix D**) and information about the nesting habits of similar species from our queen survey. These are summarized in the fact sheet called "*Habitat requirements of the Rusty-Patched Bumble Bee and other Ohio bumble bee species*".

Objective 3 was to develop a list of best management practices for the habitat of the two target bee species, which we do above. Much information about habitat management for pollinators already existed and we have reviewed this literature. Where appropriate, we have included detailed recommendations to help meet specific forage and nesting requirements of bumble bees using our data on foraging, nesting ecology and phenology, as well as the literature. We summarize this information in a fact sheet entitled "*Roadsides & The Rusty-Patched Bumble Bee: Best management practice for Ohio roadside bee habitat*". **Appendix C** lists companies that sell native seed mixes useful for bee habitat management.

Objective 4 was to develop a non-lethal protocol for surveys of the target species. This information is provided in **Appendix A**. Because the protocol is a detailed, specific, and lengthy stand-alone document, it is not condensed into a fact sheet.

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Appendix A. Protocol for non-lethal sampling of Ohio bumble bee and wildflower communities

In this document:

1. Suitable habitat for summer surveys (late May – September)

For the majority of the growing season, surveys of bumble bee communities will be most rewarding in open-grown field type habitats with lots of flowering plants. Examples of suitable habitats include:

- restored prairies or meadows that have been planted in native wildflowers and maintained to prevent regression to shrubland
- abandoned agricultural lands that are reverting to natural habitat
- hayfields and pastures *that have not been mowed within the past month or excessively grazed by livestock*
- roadsides *that have not been mowed within the past month*
- the edges of bike trails *that have not been mowed within the past month*
- urban vacant lots and gardens
- arboretums or other managed areas with large amounts of flowering plants
- areas that have been clear-cut logged *within the past two years*
- the edges of wetlands

This kind of habitat can be found on private or public lands (e.g. federal, state, county, and municipal parks and nature preserves). The main goal is find an area with lots of flowers. We recommend that sites contain **at least one acre** of wildflower habitat, to decrease the number of individual bees that you accidentally double count during the survey.

2. Suitable habitat for spring queen surveys (April – May)

In the early spring (late March to mid-May, depending on the year), the only bumble bees flying will be queens. During this time period mated queens from last summer will have newly-emerged from their winter hibernacula and begun searching for flowers and nest sites. Queens searching for nest sites are easily recognized by their zig-zagging flight pattern low over the ground. They occasionally stop to investigate a potential nest site – a hole or crevice in leaf litter, below fallen logs, in tangled roots on a stream bank, around tree bases, in piles of debris (like mulch, loose soil, or compost heaps), in tussocks of grass, or in bird houses / other human artifacts. Queens may occur in any habitat where suitable amounts of spring flowers and potential nest sites can be found, from highly urbanized areas to natural habitats. From our 2018 survey of queen bumble bees, queens are most likely to be found searching for nest sites in or near the forest, or along the boundary between the forest and an adjacent field. However, we also observed queens seeking nest sites in grasslands, around the edges of wetlands, maintained flower beds, and cemeteries and other mowed lawns.

The spring nest-founding period is a very sensitive time in the bumble bee life cycle, so **do not collect and kill queen bumble bees.** Each queen has the potential to found a nest that could produce hundreds of new reproductive offspring (males and new queens), so removing even one from the population can have a large impact.

3. Recommended non-lethal field survey methods

3a. Site description

Whether you are sampling insects, plants, birds, or any other type of organism, it is good scientific practice to collect a standard set of information about each location where you sample to characterize the habitat. We recommend for bee surveys, that you record the following information about each site:

- date (in the international/ scientific format of day-month-year, *e.g.* 12 June 2018)
- street address of the site and where to park
- GPS coordinates (in decimal degrees) marking the center of the area actually surveyed
- temperature
- cloud cover (either as % cloud cover, or a qualitative category like sunny, cloudy, partly cloudy)
- average wind speed (mph)
- start and end time of the survey in military time (e.g. 13:30 - 14:00)
- the amount of area surveyed for bees in m^2 (*e.g.* 100 m diameter circular area, or a transect 100 m x 6 m)
- the total amount of suitable bee foraging habitat at that site (*e.g.* 10 hectare field of wildflowers)
- standardized habitat category (should include categories like: deciduous forest, field, shrubby successional field, roadside, restored meadow, wetland…)
- a written site description that paints of picture of the site for the reader, or anyone planning to visit that site in the future. For example, "*Planted parkland ~20-acre meadow at the NW corner of Bainbridge St and Ravenna Rd, maintained / mowed biannually by the Geauga County Parks District. Access from public parking lot on Ravenna Rd. Surrounded by ~100 acres of deciduous forest with hiking trails. Field plant community characterized by* Rudbeckia hirta*,* Monarda fistulosa*,* Heliopsis helianthoides*,* Asclepias *spp, and* Penstemon*, with a few shrubs of bush honey suckle*."

- Draw a study site map of the main habitat types on the data sheet, then create a digital map later in Google Earth to delineate the extent of the area you surveyed or the total amount of a certain habitat type there.

3b. Flowering plant field surveys

When accompanying a bee survey, the purpose of performing a flowering plant survey is to measure the food resources available to bees at a particular date, location, and habitat type. To get meaningful information to compare to the bee data, you should measure flowering plant diversity (as a list of both the species currently in bloom *and* those being used by bumble bees) and abundance (# flower units / unit area). In floral surveys intended to give information about availability of food for bees, flower units are usually counted in "bee walkable clusters." One flower unit equals the flowers on that stem that a bee will visit before it has to take off and fly to the next flower unit. Take clovers and daisy-type flowers for example - one head (made up of many tiny flowers) = one flower unit from the bee perspective. You will need to define what consists of a flower unit separately for each flowering species you encounter.

You should choose one survey method at the start of a new field season / survey project and stick with it for the duration of the project and for all sites. It is important to use the same survey methods for all study sites in a project. Here are some different options, from simple to complex, for common ways that ecologists perform a survey of flowering plants to accompany a bee survey. We recommend method #2 below.

1. Keep a **list** of all flowering plant species you observe by habitat type and note the ones that are especially abundant and/or used by bumble bees
2. Use a wind-up meter tape to measure out a **transect** that represents a certain habitat type and *count all flower units of each species* within the transect
    - *You will need to work out the length and width of the transect you will sample ahead of time and keep it the same for all sites.* 50m x 1m, or 100m x 1m are some standard lengths and widths. In our survey we did four 25m x 1m transects per site and added those up, for a total of 100m x 1m.
    - If the flowers are patchily distributed in the habitat (large patches of thistle or milkweed, say, against a back drop of clover), then you should increase your sampling effort and do more transects
    - If the flowers are mostly uniformly distributed in the habitat, then less sampling may be sufficient to get a sense of the majority of the resources available for bees
3. Before you go out in the field, use 1/2 inch PVC pipes (held together with corner pieces) to create a 1m x 1m square frame, or "**quadrat**." In the field, delineate a larger desired sampling area that is representative of the habitat type (say a 50m diameter circular area), and toss the frame *X* number of times within that area, counting the number of flower species and units in each quadrat. *You will need to work out the number of quadrats you will sample ahead of time and keep it the same for all sites.* A common number to sample is 20 quadrats per 50m diameter circle, or 1 quadrat every 5m along a 100m transect. You should also record the total number of flowering species in the

larger area and their relative abundance (for example, by percent cover of the larger area).

3c. Bumble bee field surveys

Bee field surveys are most productive on sunny days above 70°F and less than 90°F with little wind, between the hours of 9:00 and 18:00 (6:00pm). For best results, choose study sites with at least one acre of wildflower habitat if possible to reduce the likelihood of accidentally double-counting individual bees. Because bumble bees differ somewhat by species in their food plant preferences, it is best to seek field habitat (as described above) with a diverse array of plants in bloom. Keep in mind that the first worker bumble bees do not emerge for the season until mid to late May, depending on the year, and are not abundant until early June. On the other end of the season, bumble bee species diversity drops off dramatically in August – October. Therefore, we recommend that to give a site a fair evaluation in terms of bumble bee abundance and diversity, you need to conduct your surveys in **June and July**. If you have the resources available, try to sample the same sites more than once – in June and again in July – to get a more complete picture of the bumble bee community.

There are field traps for bees that passively collect any insects that fall into them (colored bowl traps, aka "bee bowls" or "pan traps;" malaise traps; and vane traps). However, those types of traps kill large numbers of bee indiscriminately and may harm species of conservation concern. They also do not provide any information on what flowers bees rely on. Therefore, **we recommend non-lethal bee surveys only** in which trained observers conduct timed netting and observations sessions to record bees to species on the wing, Bees can also be collected in vials, photographed for later identification, and then re-released *on site*.

Before the field season begins, meet with project leaders and determine an amount of time to survey at each site. To evaluate a site for the presence of the endangered rusty-patched bumble bee (*B. affinis*), the US Fish and Wildlife Service recommends netting for 1 hour total, or until you reach 150 bumble bees (USFWS 2017). In a study of bumble bee declines in eastern North America, Colla and Packer 2008 estimated using an old dataset (MacFarlane 1974) that the likelihood of missing *B. affinis* in a sample if it were present would be less than 5% if 150 individuals were collected at a site. However, you should consider increasing the time amount if you are surveying for rare species. In our two-year statewide survey of Ohio bumble bees to search for two declining species *B. affinis* and *B. terricola* (the yellow-banded bumble bee), we surveyed for bees for **1.5 person hours (90 min)** per site. The total amount of time was divided by the number of observers working that site. For example, a four-person crew surveying a site all walked the habitat simultaneously for 22.5 minutes (90 / 4). A two-person crew surveyed simultaneously for 45 min (90 / 2). All observers should carry a stop watch and stop the timer if they need to catch and photograph a bee that he/she can't identify to species on the wing.

For each bumble bee observed during a timed survey, record the following information:

- Species of flower on which it was observed
- Social caste (queen, worker, male) if possible

- *If you observe a queen searching for a nest site or an entire nest is discovered, take a GPS point and make additional notes in a standardized format about the species, time, habitat type, and microhabitat features in an immediate area around it (leaf litter, fallen logs, grass tussocks, etc.)

Examples of blank data sheets are provided later in this document. For guidance on distinguishing between male and female bumble bees, and queen females from workers, see: https://beespotter.org/topics/key/images/male_female2008.pdf.

To increase the effectiveness of your survey, pay particular attention while netting to plant species known to attract large numbers of bumble bees. Some examples are listed in parentheses alphabetically after each category below.

- Clovers and other plants in the Fabaceae family (*Lotus corniculatus*, *Melilotus officinalis*, *Securigera varia*, *Trifolium pratense*, *Trifolium repens*)
- Mints (*Monarda fistulosa*, *Physostegia virginiana*, *Prunella vulgaris, Pycnanthemum* spp., *Teucrium canadense*)
- Milkweeds (*Asclepias incarnate*, *Asclepias syriaca*, *Asclepias tuberosa*)
- Other plants not yet mentioned that are commonly used in pollinator habitat restoration (*Helianthus* spp., *Liatris* spp., *Silphium* spp., *Veronicastrum virginicum*)
- Thistles (*Cirsium arvense*, *Cirsium discolor*, *Cirsium vulgare*)
- Other "weeds" (*Calystegia sepium, Cichorium intybus*, *Daucus carota*, *Dipsacus fullonum*, *Solanum* spp., *Verbena hastata*)
- Early-season flowering trees (*Cercis canadensis, Crataegus* spp., *Malus* spp., *Oxydendrum arboreum*, *Prunus* spp., *Robinia pseudoacacia*, *Tilia* spp.)
- Early-season flowering shrubs and canes (*Vaccinium* spp., *Rhododendon* spp., *Lonicera* spp., *Elaeagnus umbellata, Rosa* spp., *Rubus* spp.)

4. Suggestions for data analysis

Once you have entered the data, and done quality control checks, there some basic statistical tests you can use for comparing bumble bee diversity and abundance by time of season and site features (flower diversity, flower abundance, habitat type, site size) (see table below).

Response variables	Explanatory variables	Type of statistical test
bee diversity, bee abundance	Categorical variable with only two levels (*e.g.* roadside vs not, June vs July, or 2018 vs 2019)	t-test
bee diversity, bee abundance	Categorical variable with 3+ levels (*e.g.* habitat type, year if long-term monitoring project)	Analysis of variance (ANOVA)
bee diversity, bee abundance	Continuous variable (flower diversity, flower abundance, site size)	correlation

Some simple graphs you can make in Excel or basic statistical software include bar graphs (**Figure 1**), histograms (**Figure 2**), scatterplots (**Figure 3**), or box and whisker plots (**Figure 4**).

Field Survey Methods References

Colla SR, Packer L. 2008. Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. Biodiversity and Conservation 17: 1379-1391

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United States Fish and Wildlife Service (USFWS). 2017b. Rusty patched bumble bee guidance for surveyors and researchers. Accessed 1 May 2017 from https://www.fws.gov/midwest/endangered/insects/rpbb/surveys.html

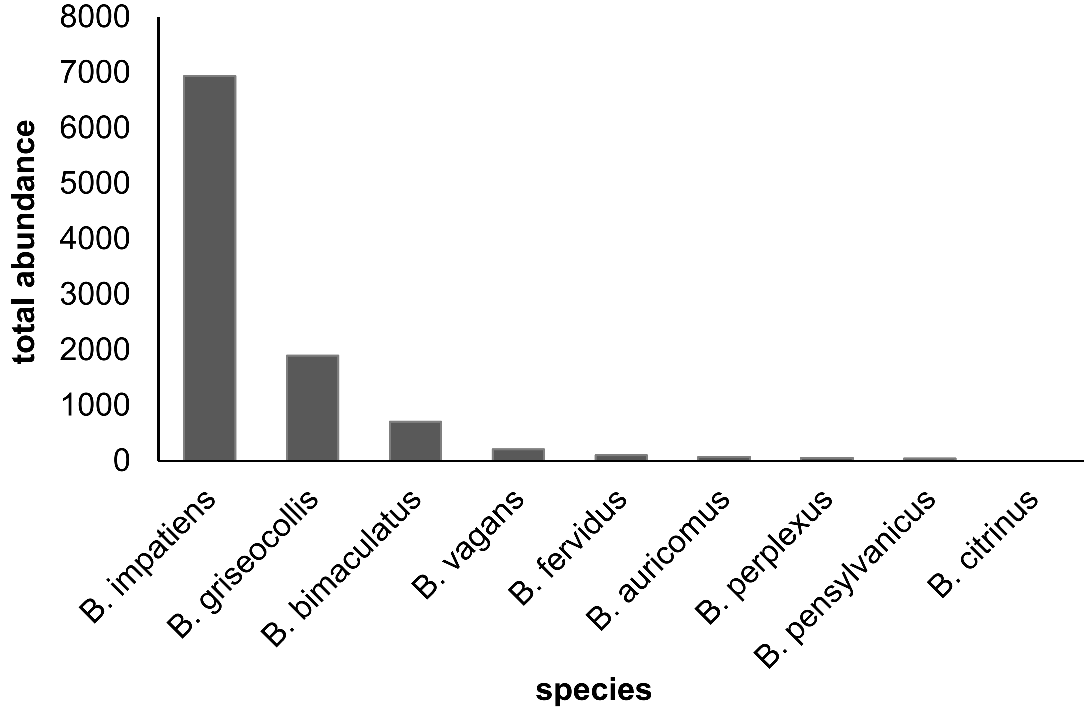

Figure 1. Bar graph of the total number of bumble bees collected by species in a summer 2017 survey of 130 sites. The genus *Bombus* is abbreviate as "B." in species names.

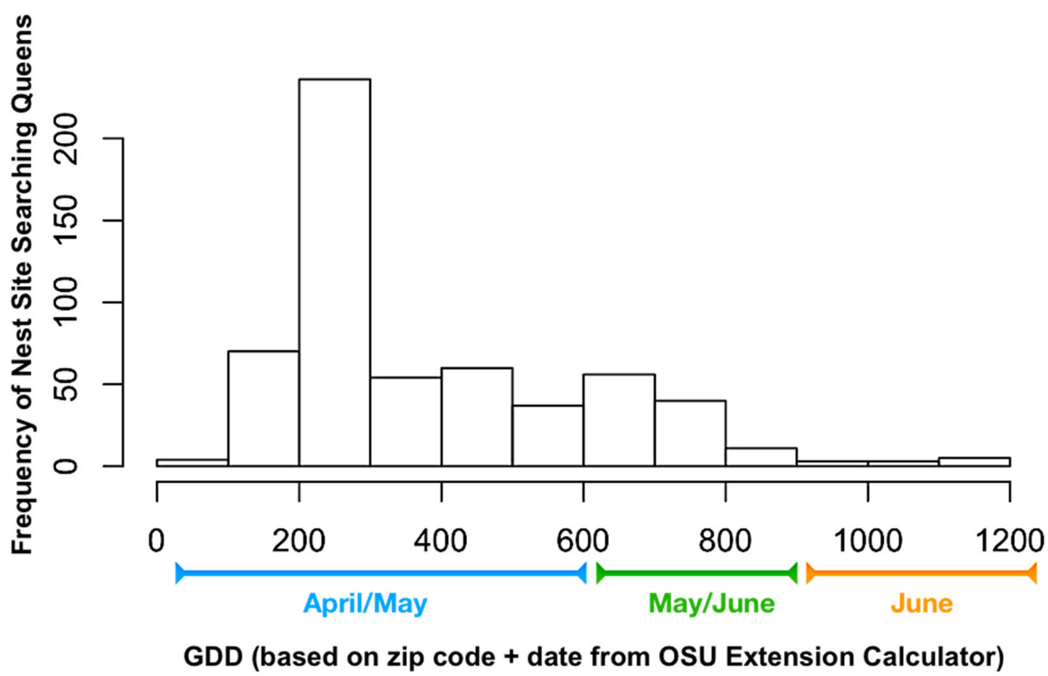

Figure 2. Histogram of the number of queens searching for nest sites by cumulative growing degree day of the season (GDD). GDD was calculated using the Ohio State University Extension online calculator from the sample date and zip code of each study site. The month associated with GDD in this study are given by colored bars below the x axis.

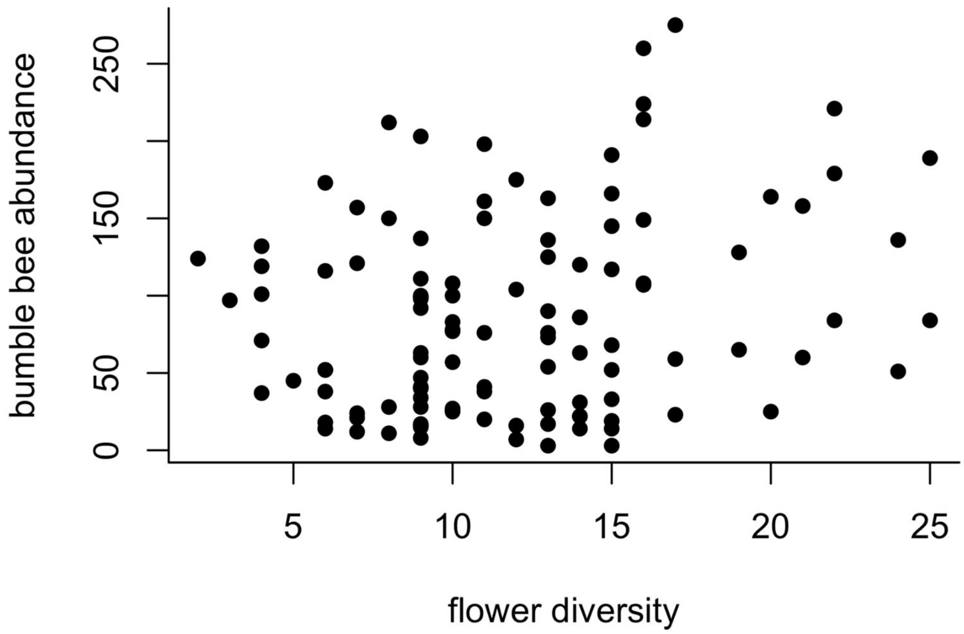

Figure 3. Scatterplot of the number of bumble bees collected per 90 min sample versus the number of flowering species in a summer 2017 survey of 130 sites.

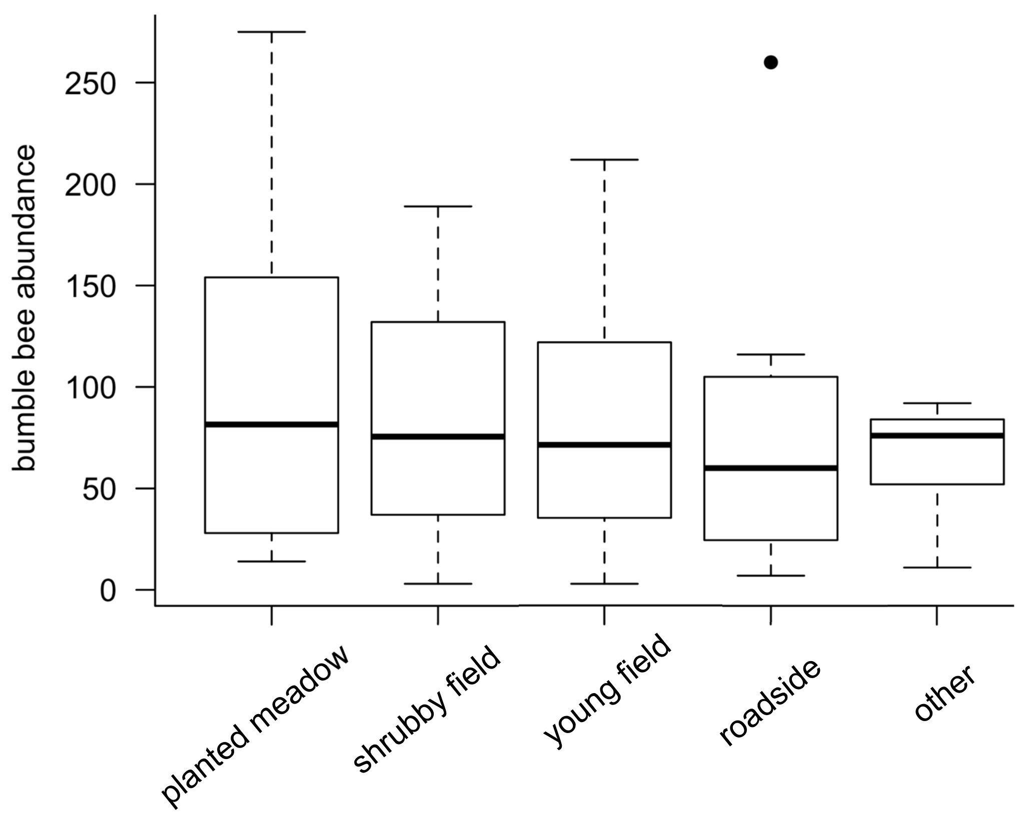

Figure 4. Box and whisker plots of the number of rare bumble bees collected per 90 min sample versus the habitat type in a summer 2017 survey of 130 sites. Rare bumble bees included *Bombus auricomus*, *B. fervidus*, *B. pensylvanicus*, *B. perplexus*, and *B. vagans*.

5. Recommended Identification Resources for Bumble Bees

Bumble Bees of North America: an Identification Guide (2014) by Paul Williams, Robbin Thorpe, Leif Richardson, and Sheila Colla. https://www.amazon.com/Bumble-Bees-North-America-Identification/dp/0691152225/ref=sr_1_2?ie=UTF8&qid=1521671217&sr=8-2&keywords=bumble+bee+book

Electronic resources

- **Beespotter**, a pollinator conservation organization that collects bee observation data from the public:
    - **Dichotomous Key** https://beespotter.org/topics/key/images/BumbleBeeKey2016.pdf
    - **Field Guide style** https://beespotter.org/topics/key/images/BumbleBeeFieldguideAlt4.pdf
- **Discoverlife,** an interactive dichotomous key made by expert bee scientists https://www.discoverlife.org/mp/20q?guide=Bombus
- **Bumble Bees of the Eastern US**, a field guide by Colla, Richardson, and Williams that was produced in partnership with the US Forest Service, the USDA, and Pollinator Partnership: https://www.fs.fed.us/wildflowers/pollinators/documents/BumbleBeeGuideEast2011.pdf

6. Recommended Identification Resources for Wildflowers

Newcomb's Wildflower Guide (1989) by Lawrence Newcomb. Little, Brown and Company: Boston, MA ISBN13: 978-0-316-60442-9. https://www.amazon.com/Newcombs-Wildflower-Guide-Lawrence-Newcomb/dp/0316604429/ref=sr_1_1?s=books&ie=UTF8&qid=1539108846&sr=1-1&keywords=newcomb%27s+wildflower+guide

Wildflowers of Ohio (2008) by Robert Henn. Indiana University Press. ISBN 9780253219510. https://www.amazon.com/Wildflowers-Ohio-Second-Robert-Henn/dp/0253219515

When entering data, check to ensure you have the most up to date scientific name for each plant species with the USDA Plants Database: https://plants.usda.gov/java/

7. Examples of blank bee and flower survey data sheets.

On the following pages, we provide examples of bee, plant, and habitat datasheets for field surveys. These were used in the 2017 – 2018 statewide Ohio bumble bee survey conducted by researchers at the Ohio State University and the University of Akron.

BEE DATA SHEET

Site ________________________________ Date _________________ Time & Duration of survey: _____________

Observer initials: ______________________ sun/cloud cover _______ Temp ________ wind speed_________

Write in bee species as row names, making separate rows for each species by social caste. Write in plant species as column names. The cell values should be the number of that bee of that caste observed on that plant species.

Bee species	Caste								

Site ________________________ Date ____________ Bee Data page __ of __

PLANT DATA SHEET

Site ________________________________ Date ________________ Time of survey: _____________________

Observer initials: ______________________

Write plant species as the column names in the first row. For transects 1 - 4 write the of number of floral units of each species in each cell. Please sketch or describe floral unit for each species (e.g., Trifolium: Floral unit = inflorescence) if not established.

Transect																
1																
2																
3																
4																

SITE / HABITAT DESCRIPTION DATA SHEET

Site ______________________________ Date ___________________ Observers ________________________

Attribute	Description	Quantity			
		Absent	Low (1-5)	Medium (5-20)	High (>20)
Rocks	Count rocks > 0.5 m diameter				
Bare ground	Count 0.5 m diameter increments				
Grass tussocks	Count				
Trees	Standing twigs / Dead wood/logs				
Variation in vegetation height	How does the height position of floral resources vary within the site?	< 0.5 m in height	0.5 – 1.5 m height	> 1.5 m height (tall plants/shrubby)	

Habitat elements: The following characteristics should be recorded for the *entire netted habitat area*

Habitat Type (circle one):

Shrubby successional old field

Natural Field (recently, abandoned, no shrubs)

Meadow intentionally planted with wildflowers

Roadside

Mowed lawn

Urban planted patch (e.g. arboretum, landscaping/ personal garden)

Other

If Other, explain:

Site description & sketch map: (size, slope, where you sampled, additional notes):

plant species	common	family	native or introduced?	Bombus visits	Bombus species count (aur_pen lumped; Bsp omitted)	flower abundance in transect surveys	Bombus aur_pen	Bombus bimaculatus	Bombus borealis	Bombus citrinus	Bombus fervidus	Bombus griseocollis	Bombus impatiens	Bombus perplexus	Bombus vagans	Bombus sp	Bombus aur/pen	Bombus auricomus	Bombus pensylvanicus
Monarda fistulosa	wild bergamot	Lamiaceae	native	4825	7	33868	219	1031	0	0	37	1297	2182	15	85	12	73	121	25
Trifolium pratense	red clover	Fabaceae	introduced	2838	7	60304	128	735	0	0	137	498	1173	17	189	5	47	51	30
Securigera varia	crown vetch	Fabaceae	introduced	1685	7	80002	12	273	0	0	8	520	791	36	34	8	4	6	2
Asclepias syriaca	milkweed	Asclepiadaceae	native	1287	6	4747	0	34	0	0	1	1203	40	3	5	1	0	0	0
Dipsacus spp.	teasel	Dipsacaceae	introduced	1093	8	3901	4	50	1	0	20	423	548	4	40	2	0	2	2
Penstemon digitalis	foxglove beardtongue	Scrophulariaceae	native	902	8	19754	17	506	0	1	23	41	243	32	38	0	15	1	1
Lotus corniculatus	birdsfoot trefoil	Fabaceae	introduced	745	5	72494	0	21	0	0	40	175	458	0	51	0	0	0	0
Ratibida pinnata	pinnate prairie coneflower	Asteraceae	native	713	6	35465	3	27	0	0	4	596	75	0	2	4	1	1	1
Silphium spp.	rosinweed	Asteraceae	native	705	7	4236	2	12	0	0	1	70	608	6	2	2	0	2	0
Cirsium arvense	Canada thistle	Asteraceae	introduced	643	7	20228	2	38	0	0	5	198	368	10	13	8	0	2	0
Echinacea purpurea	purple coneflower	Asteraceae	native	612	6	5980	12	33	0	0	0	359	201	1	7	2	3	7	2
Trifolium repens	white clover	Fabaceae	introduced	534	6	26652	0	53	0	0	7	65	390	3	16	0	0	0	0
Solidago spp.	goldenrod	Asteraceae	native	498	3	10947	0	0	0	0	0	8	488	0	2	0	0	0	0
Pycnanthemum tenuifolium	narrowleaf mountain mint	Lamiaceae	native	420	4	19191	0	10	0	0	1	84	325	0	0	0	0	0	0
Erynguim yuccifolium	rattlesnake master	Apiaceae	native	341	3	7194	0	3	0	0	0	15	323	0	0	0	0	0	0
Daucus carota	Queen Anne's lace	Apiaceae	introduced	338	3	20289	0	0	0	0	1	6	331	0	0	0	0	0	0
Heliopsis helianthoides	smooth oxeye	Asteraceae	native	336	5	13707	0	11	0	0	1	123	199	0	2	0	0	0	0
Verbesina alternifolia	wingstem	Asteraceae	native	330	2	3576	0	0	0	0	0	2	328	0	0	0	0	0	0
Vicia spp.	vetch	Fabaceae	both	328	7	5600	5	58	0	0	15	156	78	1	15	0	2	3	0
Prunella vulgaris	selfheal	Lamiaceae	native	315	6	5754	4	11	0	0	17	17	243	0	25	0	2	0	2
Chamaecrista fasciculata	patridge pea	Fabaceae	native	280	4	12683	2	0	0	0	1	15	262	0	0	0	1	1	0
Asclepias tuberosa	butterfly milkweed	Asclepiadaceae	native	239	5	2469	1	11	0	0	0	159	64	0	2	2	0	0	1
Melilotus alba	white sweetclover	Fabaceae	introduced	226	6	29829	0	24	0	0	2	41	153	2	3	1	0	0	0
Eutrochium fistulosum	trumpetweed	Asteraceae	native	220	4	2570	0	0	0	0	1	45	172	0	2	0	0	0	0
Apocynum cannabinum	indianhemp	Apocynaceae	native	178	5	7004	0	9	0	0	0	104	60	3	2	0	0	0	0
Trifolium hybridum	alsike clover	Fabaceae	introduced	173	7	31191	2	21	0	0	4	13	122	1	10	0	1	0	1
Melilotus officinalis	yellow sweetclover	Fabaceae	introduced	163	6	23375	0	51	0	0	1	68	31	1	10	1	0	0	0
Centaurea spp.	knapweed	Asteraceae	both	151	5	2572	2	7	0	0	0	48	94	0	1	0	1	0	1
Cichorium intybus	chichory	Asteraceae	introduced	151	7	4603	2	23	0	0	2	43	72	1	8	1	1	1	0
Rudbeckia hirta	blackeyed susan	Asteraceae	native	111	4	38132	4	0	0	0	0	64	42	0	1	0	1	2	1
Vernonia spp.	ironweed	Asteraceae	native	107	4	4038	1	0	0	0	0	11	93	0	2	0	0	1	0
Calystegia sepium	hedge false bindweed	Convulvulaceae	both	105	7	617	1	26	0	0	5	44	21	2	6	0	0	0	1
Senna hebecarpa	American senna	Fabaceae	native	94	4	384	1	3	0	0	0	12	78	0	0	0	0	1	0
Convolvulus arvensis	field bindweed	Convulvulaceae	introduced	90	5	683	1	60	0	0	0	8	19	0	1	1	0	1	0
Lythrum salicaria	purple loosestrife	Lythraceae	introduced	89	4	3193	1	0	0	0	0	8	76	0	4	0	0	0	1
Cirsium vulgare	bull thistle	Asteraceae	introduced	86	5	135	0	6	0	0	2	18	59	0	1	0	0	0	0
Liatris spp.	blazing star	Asteraceae	native	86	5	1877	0	3	0	0	1	46	35	0	1	0	0	0	0
Plantago lanceolata	narrowlead platain	Plantaginaceae	introduced	79	1	9959	0	0	0	0	0	0	79	0	0	0	0	0	0
Gaillardia pulchella	indian blanket	Asteraceae	native	72	4	227	0	8	0	0	0	47	15	2	0	0	0	0	0
Helianthus spp.	sunflower	Asteraceae	native	71	4	971	0	1	0	0	0	30	39	0	1	0	0	0	0
Hypericum (shrub spp.)	St. John's wort	Clusiaceae	both	70	4	106	0	6	0	0	0	4	54	0	6	0	0	0	0
Asclepias incarnata	swamp milkweed	Asclepiadaceae	native	69	3	599	0	1	0	0	0	59	9	0	0	0	0	0	0
Hypericum (herb spp.)	St. John's wort	Clusiaceae	both	69	4	1203	0	6	0	0	0	1	57	0	5	0	0	0	0
Veronicastrum virginicum	Culver's root	Scrophulariaceae	native	66	5	142	0	2	0	0	1	3	58	0	2	0	0	0	0
Pycnanthemum muticum	clustered mountainmint	Lamiaceae	native	62	2	2829	0	0	0	0	0	39	22	0	0	1	0	0	0
Impatiens capensis	jewelweed	Balsaminaceae	native	56	3	774	0	0	0	0	1	0	53	0	2	0	0	0	0
Verbena hastata	swamp verbena	Verbenaceae	native	52	6	3870	0	3	0	0	1	10	31	1	6	0	0	0	0
Lathyrus latifolius	perennial pea	Fabaceae	introduced	51	5	1817	4	6	0	0	1	37	3	0	0	0	0	4	0

Company		n/a	Ernst Seed	Ernst Seed	Ernst Seed	Ernst Seed
Seed Mix Name		recommended seed mix for bumble bees	Mesic/Dry Native Pollinator Mix	Mesic/dry Native Pollinator Mix w/o Grasses	Partially Shaded Roadside Mix	Showy Northeast Native Wildflower & Grass Mix
price / lb		n/a	31.88	98.73	36.81	31.47
recommended seeding rate		n/a	20 lbs / acre	5 - 10 lbs / acre if planted with 30 lbs / acre of a cover crop like oats or rye	20 lbs / acre	20 lbs / acre
cost per acre at recommended seeding rate		n/a	637.6	740.475	736.2	629.4
Grasses						
Agrostis perennans	**Autumn Bentgrass**				0.50	
Bouteloua curtipendula	**Sideoats Grama**	X				26.50
Bouteloua gracilis	**Blue Grama**					
Carex breviary	**Plains Oval Sedge**					
Carex vulpinoidea	**Brown Fox Sedge**					
Elymus canadensis	**Canada Wildrye**	X				
Elymus hystrix	**Bottlebrush Grass**				1.00	
Elymus riparius	**Riverbank Wildrye**					
Elymus virginicus	**Virginia Wildrye**		20.00		19.00	14.00
Juncus dudleyi	**Dudley’s Rush**					
Koeleria macrantha	**June Grass**					
Panicum clandestinum	**Deer tongue**		5.00			
Panicum sphaeroncarpon	**Round Seed Panicgrass**				17.70	
Schizachyrium scoparium	**Little Bluestem**	X	27.00		39.80	35.00
Sorghastrum nutans	**Indiangrass**	X	15.00			
Sporobolus compositus	**Rough Dropseed**					
Sporobolus heterolepis	**Prairie Dropseed**					
Tridens flavus	**Purpletop**		5.00			
Forbs						
Achillea millefolium	**Yarrow**					
Agastache foeniculum	**Anise Hyssop**	X				
Allium cernuum	**Nodding Onion**					
Allium stellatum	**Prairie Onion**					
Anemone virginiana	**thimbleweed**				0.40	
Apocynum cannabinum	**Dogbane**					
Asclepias incarnata	**Swamp Milkweed**	X	1.00	3.00		
Asclepias syriaca	**Common Milkweed**	X	0.30	0.50	0.30	
Asclepias tuberosa	**Butterfly Milkweed**	X			0.50	2.00

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Asclepias verticillata	Whorled Milkweed					
Aster laevis	Smooth Blue Aster	X	0.70	5.00	0.40	1.00
Aster macrophyllus	Bigleaf Aster				0.50	
Aster novae-angliae	New England Aster	X	0.90	3.00		0.60
Aster oblongifolius	Aromatic aster					0.10
Aster pilosus	Frost Aster					
Aster prenanthoides	Zigzag Aster				0.50	0.10
Aster umbellatus	Flat-topped White Aster	X				
Astragalus canadensis	Canadian Milk Vetch	X				
Baptisia alba	White Wild Indigo					
Baptisia australis	Blue False Indigo	X	0.40	1.00	0.50	0.50
Baptisia tinctoria	Yellow False Indigo				0.10	0.10
Bidens aristosa	Swamp Marigold					
Boltonia asteroidea	False Aster					
Chamaecrista fasciculata	partridge pea	X	4.00	9.50	4.00	3.00
Coreopsis lanceolata	Lanceleaf Coreopsis		3.00	12.00		3.00
Coreopsis palmata	Prairie Coreopsis					
Coreopsis tinctoria	Plains Coreopsis					
Dalea candida	White Prairie Clover					
Dalea purpurea	Purple Prairie Clover	X				
Desmanthus illinoensis	Illinois Bundleflower					
Drymocallus arguta	Prairie Cinquefoil					
Echinacea pallida	Pale Purple Coneflower					
Echinacea purpurea	Purple Coneflower	X	3.00	12.00	3.50	3.50
Eryngium yuccifolium	Rattlesnake Master	X				
Eupatorium fistulosum	Joe Pye Weed		0.10	0.10		
Eupatorium perfoliatum	Boneset		0.30	0.30		
Eupatorium rugosum	White Snakeroot		0.10	0.10		
Euthamia graminifolia	Grass-Leaved Goldenrod	X				

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Gaillardia aristata	Blanket Flower					
Gaillardia pulchella	Indian Blanket					
Gaura biennis	Biennial Gaura					
Gaura longifolia	large-flowered aura					
Gentianella quinquefolia	Stiff Gentian					
Geum canadense	White Avens		0.50	1.50	0.50	
Helianthus pauciflorus	Showy sunflower					
Heliopsis helianthoides	Oxeye Sunflower	X	2.00	6.00	2.00	2.00
Lespedeza capitata	Roundhead Lespedeza		0.30	1.00		
Liatris ligulistylis	Meadow Blazing Star					
Liatris pycnostachya	Prairie Blazing Star	X				
Liatris spicata	Marsh (Dense) Blazing Star		1.00	5.00	1.00	1.00
Lobelia siphitica	Great Blue Lobelia					
Medicago sativa	Alfalfa					
Monarda citriodora	Lemon mint					
Monarda fistulosa	Wild Bergamot	X	0.40	1.60	0.40	0.40
Monarda punctata	Spotted Bee Balm					
Orbexilum pedunculatum	Sampson's snakeroot					
Parthenium integrifolium	wild Quinine					
Penstemon digitalis	Tall White Beardtongue	X	2.00	12.00	2.00	2.00
Penstemon hirsutus	Hairy Beardtongue				0.10	0.10
Pycnanthemum tenuifolium	Narrowleaf Mountainmint	X	0.30	1.50	0.50	0.30
Pycnanthemum verticillatum var. pilosum	Hairy Mountain Mint					
Pycnanthemum virginianum	Mountain Mint					
Ratibida pinnata	Grey-Headed Coneflower	X				
Rudbeckia fulgida	Orange Coneflower					0.10
Rudbeckia hirta	Blackeyed Susan	X	3.00	12.00	3.00	3.00
Rudbeckia triloba	Brown-eyed Susan					

Company		n/a	Ernst Seed	Ernst Seed	Ernst Seed	Ernst Seed
Seed Mix Name		**recommended seed mix for bumble bees**	**Mesic/Dry Native Pollinator Mix**	**Mesic/dry Native Pollinator Mix w/o Grasses**	**Partially Shaded Roadside Mix**	**Showy Northeast Native Wildflower & Grass Mix**
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cost per acre at recommended seeding rate		n/a	637.6	740.475	736.2	629.4
Scrophularia lanceolata	**Early Figwort**					
Senna hebecarpa	**Wild Senna**	X	0.50	2.00		0.40
Senna marilandica	**Maryland Senna**					0.10
Silphium terebinthinaceum	**Prairie Dock**	X				
Solidago bicolor	**White Goldenrod**				0.50	
Solidago juncea	**Early Goldenrod**	X	0.20	0.50	0.20	0.10
Solidago nemoralis	**Gray Goldenrod**		0.10	0.20		0.10
Solidago ohioensis	**Ohio Goldenrod**					
Solidago rigida	**Stiff Goldenrod**	X				
Solidago rugosa	**Wrinkleleaf Goldenrod**	X	0.10	0.20		
Solidago speciosa	**Showy Goldenrod**					
Tradescantia ohiensis	**Ohio Spiderwort**		0.30	2.00	0.50	0.50
Trifolium pratense	**Red Clover**	X				
Trifolium repens	**White Clover**					
Verbena hastata	**Blue Vervain**	X	3.00	6.00		
Verbena stricta	**Hoary Vervain**					
Vernonia noveboracensis	**New York Ironweed**					
Veronicastrum virginicum	**culver's root**	X			0.10	
Zizia aurea	**Golden Alexanders**	X	0.50	2.00	0.50	0.50
Woody Plants						
Amorpha canescens	**Lead Plant**					
Caenothus americanus	**New Jersey Tea**					
Hypericum prolificum	**Shrubby St John's Wort**					
cell values are % dry weight that a species makes up in a specific seed mix. If % is not provided on the nursery's website, given as an X						

Ernst Seed	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Prairie Moon Nursery	Prairie Moon Nursery	Prairie Moon Nursery
Showy Northeast Native Wildflower & Grass Mix	**20th Anniversary Prairie Native Seed Mix**	**Eastern Great Lakes Native Pollinator Mix**	**Empire State Honey Producers Association Roadside Bee Forage Mix**	**Ohio Pollinator Oasis Native Seed Mix**	**Pollinator-Palooza Seed Mix**	**Pretty Darn Quick (PDQ) Seed Mix**	**Insectopia**
107.51	52.00	95.62	42.00	114.44	161.15	84.69	131.22
5 - 10 lbs / acre if planted with 20 lbs / acre of a cover crop like oats or rye	12	10	10	10	6.59	10.65	8.52
806.325	624	956.2	420	1144.40	1062.00	902	1118.00
	X	X			15.16	18.77	7.34
	X						
						2.35	
						1.17	
	X	X			6.63	9.38	11.74
		X					
	X	X					
					0.95	0.59	
					2.37		3.67
	X	X			15.16	14.08	16.14
					2.84		
					0.95		1.47
							0.37
					0.95	0.59	1.10
					0.95		1.47
						1.17	
							0.37
				X	1.89	1.17	1.10
		X		X	1.42		0.92
5.00		X		X	0.95		1.10

Ernst Seed	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Prairie Moon Nursery	Prairie Moon Nursery	Prairie Moon Nursery
Showy Northeast Native Wildflower & Grass Mix	**20th Anniversary Prairie Native Seed Mix**	**Eastern Great Lakes Native Pollinator Mix**	**Empire State Honey Producers Association Roadside Bee Forage Mix**	**Ohio Pollinator Oasis Native Seed Mix**	**Pollinator-Palooza Seed Mix**	**Pretty Darn Quick (PDQ) Seed Mix**	**Insectopia**
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806.325	624	956.2	420	1144.40	1062.00	902	1118.00
					1.89		0.37
1.00	X	X		X	1.42	1.17	0.92
1.00	X	X		X			
3.00							0.37
	X			X			
3.00							
			X				
	X			X		0.29	
		X			0.47		
1.00							
0.20							
						0.59	
				X			
12.00			X	X	4.74	18.77	11.74
12.00	X	X		X	2.84	2.93	5.68
							0.37
		X					
	X	X		X		1.76	2.57
	X	X		X	2.84	2.35	3.30
				X			
						0.59	0.73
					2.84		
12.00	X	X		X	1.89	3.52	
				X	1.89	1.17	2.93
				X			0.18

Ernst Seed	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Prairie Moon Nursery	Prairie Moon Nursery	Prairie Moon Nursery
Showy Northeast Native Wildflower & Grass Mix	**20th Anniversary Prairie Native Seed Mix**	**Eastern Great Lakes Native Pollinator Mix**	**Empire State Honey Producers Association Roadside Bee Forage Mix**	**Ohio Pollinator Oasis Native Seed Mix**	**Pollinator-Palooza Seed Mix**	**Pretty Darn Quick (PDQ) Seed Mix**	**Insectopia**
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806.325	624	956.2	420	1144.40	1062.00	902	1118.00
	X			X			
	X	X	X	X			
						0.59	
					0.47		
						0.29	
					0.24		0.37
6.00			X	X		0.59	3.67
					0.47		
					1.89		
					1.89		1.47
5.50		X					
					0.95	1.17	0.59
			X				
	X	X		X			
1.50	X	X		X	0.47	0.59	0.73
							1.47
		X					
					0.24		1.83
12.00	X		X		0.95	1.17	
0.10							
1.50							
					0.50		
					1.01	0.59	1.10
	X	X		X	0.47	0.59	0.73
0.20							
12.00	X	X	X	X	5.68	7.04	2.20
					0.24	0.29	

Ernst Seed	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Ohio Prairie Nursery	Prairie Moon Nursery	Prairie Moon Nursery	Prairie Moon Nursery
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806.325	624	956.2	420	1144.40	1062.00	902	1118.00
					0.60		0.11
1.40					1.01		
0.20							
		X					
0.20					0.47		
0.20				X			
			X				
		X		X	0.95		
				X	0.47	0.59	0.55
6.00		X			2.84		2.20
			X				
			X				
			X		0.95	1.17	
						0.59	1.83
		X		X			
					0.47		0.09
3.00		X		X	2.84	2.35	4.40
					0.95		
					0.95		0.73
					0.95		

authors (listed in order as on paper. format: last name + first initials without periods, comma separated list)	article title	year of publication	journal name (not abbreviated)	Volume	issue #	page numbers	country of origin of first author	category(s): declines and distributions, flower resource use, habitat, nesting/reproduction, general (bumble bee biology)	keywords (comma separated list). If in [ ] that means they are our keywords not the authors
Arbetman MP, Gleiser G, Morales CL, Williams P, Aizen MA	Global decline of bumblebees is phylogenetically structured and inversely related to species range size and pathogen incidence	2017	Proceedings of the Royal Society B	284	n/a	e20170204	Argentina	declines and distributions	Bombus, Crithidia bombi, IUCN red list, Locustacarus buchneri, Nosema spp., pollinator decline
Becher AM, Twiston-Davies, Penny TD, Goulson D, Rotheray EL, Osborne JL	*Bumble* -BEEHAVE: A systems model for exploring multifactorial causes of bumblebee decline at individual, colony, population and community level	2018	Journal of Applied Ecology	55	n/a	2790-2801	UK	declines and distributions	agent-based modeling, Bombus terrestris, bumblebees, colony decline, cross-level interactions, foraging, multiple stressors, pollination
Bommarco R, Lundin O, Smith HG, Rundlof M	Drastic historic shifts in bumble-bee community composition in Sweden	2012	Proceedings of the Royal Society B	279	n/a	309-315	Sweden	declines and distributions	Bombus spp, ecosystem service, pollination, Trifolium pratense, red clover
Brian AD	The foraging of bumble bees Part II. Bumble bees as pollinator	1954	Bee World	35	5	81-91	England	declines and distributions	[none]
Brown MJF	The trouble with bumblebees	2011	Nature	469	n/a	169	UK	declines and distributions	[none]
Brown MJF, Paxton RJ	The conservation of bees: a global perspective	2009	Apidologie	40	n/a	410-416	UK	declines and distributions	Apoidea, biodiversity, pollination, conservation, ecosystem service
Byrne A, Fitzpatrick Ú	Bee conservation policy at the global, regional and national levels	2009	Apidologie	40	n/a	194-210	Ireland	declines and distributions	conservation, policy, bee, international pollinator initiative, legislation
Cameron SA, Lim HC, Lozier JD, Duennes MA, Thorp R	Test of the invasive pathogen hypothesis of bumble bee decline in North America	2016	Proceedings of the National Academy of Science	113	16	4386-4391	USA	declines and distributions	Bombus, microsporidia, Nosema bombi, pollinator, conservation
Cameron SA, Lozier JD, Strange JP et al.	Patterns of wide-spread decline in North American bumble bees	2011	Proceedings of the National Academy of Science	108	n/a	662–667	USA	declines and distributions	none
Colla SR, Dumesh S	The bumble bees of southern Ontario: Notes on natural history and distribution	2010	Journal of the Entomological Society of Ontario	141	n/a	39-68	Canada	declines and distributions	[natural history, distribution, literature review, Bombus spp, phenology, food plants]
Colla SR, Gadallah F, Richardson L, Wagner D, Gall L	Assessing declines of North American bumble bees *(Bombus* spp.) using museum specimens	2012	Biodiversity and Conservation	21	n/a	3585-3595	Canada	declines and distributions	pollinator decline, bumble bees, Bombus, grid cell, museum data, insect collections
Colla SR, Packer L	Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on Bombus affinis Cresson	2008	Biodiversity and Conservation	17	n/a	1379-1391	Canada	declines and distributions	bee conservation, bumblebees, pollinator decline, Bombus affinis, species diversity, species rane, relative abundance
Darvill B, Ellis JS, Lye GC, Goulson D	Population structure and inbreeding in a rare and declining bumblebee, Bombus muscorum (Hymenoptera: Apidae)	2006	Molecular Ecology	15	n/a	601-611	UK	declines and distributions	Bombus, diploid males, Hymenoptera, inbreeding, microsatellites, populations genetics

authors (listed in order as on paper. format: last name + first initials without periods, comma separated list)	article title	year of publication	journal name (not abbreviated)	Volume	issue #	page numbers	country of origin of first author	category(s): declines and distributions, flower resource use, habitat, nesting/reproduction, general (bumble bee biology)	keywords (comma separated list). If in [ ] that means they are our keywords not the authors
De Keyzer CW, Colla SR, Kent CF, Rafferty NE, Richardson LL, Thomson JD	Delving deeper: Quesitoning the decline of long-tongued bumble bees, long-tubed flowers and their mutualisms with climate change	2016	Journal of Pollination Ecology	18	6	36-42	Canada	declines and distributions	adaptive evolution, Bombus, bumblebee, climate change, phenotypic plasticity, tongue length
Ellis JS, Knight ME, Darvill B, Goulson D	Extremely low effective population sizes, genetic structuing and reduced genetic diversity in a threatened bumblebee species, Bombus sylvarum (Hymenoptera: Apidae)	2006	Molecular Ecology	15	n/a	4375-4386	UK	declines and distributions	Bombus, conservation, microsatellites, nest-density, population genetics
Environment and Climate Change Canada	Recovery Strategy for the Rusty-patched Bumble Bee (Bombus affinis) in Canada	2016	Minister of Environment and Climate Change	7	n/a	56	Canada	declines and distributions	[none]
Evans E, Thorp R, Jepsen S, Hoffman Black S	Status review of three formerly common species of bumble bee in the subgenus Bombus	2008	the Xerces Society	n/a	n/a	n/a	USA	declines and distributions	[none]
Federman A	Plight of the bumblebee	2009	Earth Island Journal	n/a	n/a	34-39	n/a	declines and distributions	[none]
Figueroa LL, Bergey EA	Bumble bees (Hymenoptera: Apidae) of Oklahoma: Past and present biodiversity	2015	Journal of the Kansas Entomological Society	88	4	418-429	USA	declines and distributions	Bombus, pollinator decline, entomological collections, bee conservation, regional fauna
Franklin HJ	The Bombidae of the New World	1912	Transactions of the American Entomological Society	38	n/a	177-486	USA	declines and distributions	[none]
Frison TH	Biological studies of the Bremidae of Illinois	1918	University of Illinois Research Bulletin	n/a	n/a	n/a	USA	declines and distributions	[none]
Frison TH	Biological studies of the Bremidae or bumblebees with special reference to the species occuring in Illinois	1923	University of Illinois Research Bulletin	n/a	n/a	n/a	USA	declines and distributions	[none]
Fye RE	The bionomics of the bumblebees of Wisconsin	1954	University of Wisconsin Research Bulletin	n/a	n/a	n/a	USA	declines and distributions	[none]
Goulson D, Hanley ME, Darvill B, Ellis JS, Knight ME	Causes of rarity in bumblebees	2005	Biological Conservation	122	n/a	8-Jan	UK	declines and distributions	Hymenoptera, Bombus, abundance, tongue length, pollen, competition
Goulson D, Lye GC, Darvill B	Decline and conservation of bumble bees	2008	Annual Review of Entomology	53	n/a	191-208	UK	declines and distributions	Hymenoptera, Bombus, rarity, population structure, habitat loss
Goulson D, Nicholls E, Botias C, Rotheray EL	Bee declines driven by combined stress from parasites, pesticides, and lack of flowers	2015	Science	347	6229	doi: 10.1126/science.1255957	UK	declines and distributions	[none]

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Graenicher S	Bee-fauna and vegetation of wisconsin	1935	Annals of the Entomological Society of America	28	2	285-310	USA	declines and distributions	[none]
Habel JC, Schmitt T	Vanishing of the common species: Empty habitats and the role of genetic diversity	2018	Biological Conservation	218	n/a	211-216	Germany	declines and distributions	inbreeding depression, fragmented landscapes, extinction risk, biodiversity, butterflies, populations, grasslands, belgium, fitness, teleius
Hanley N, Breeze TD, Ellis C, Goulson D	Measuring the economic value of pollination services: Principles, evidence, and knowledge gaps	2015	Ecosystem Services	14	n/a	124-132	UK	declines and distributions	pollination, bees, economic value, ecosystem services, natural capital assets, thresholds
Hatfield R, Jepsen S, Thorp R, Richardson L, Colla S, Foltz Jordan S, Evans E	Rusty Patched Bumble Bee (Bombus affinis) Additional supporting Information	n/a	IUCN Red List of Threatened Species	n/a	n/a	n/a	n/a	declines and distributions	[none]
Hatfield R, Jepsen S, Thorp R, Richardson L, Colla S, Foltz Jordan S, Evans E	Bombus affinis, Rusty Patched Bumble Bee	2015	IUCN Red List of Threatened Species	n/a	n/a	n/a	USA	declines and distributions	[none]
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. I. Subgenus *Alpinobombus* Skor.	1964	The Canadian Entomologist	96	n/a	1465-1470	Canada	declines and distributions	[none]
Inouye D, Droege S, Mawdsley J	Words alone will not protect pollinators	2017	Science letters	355	6323	n/a	USA	declines and distributions	[none]
Jacobson MM, Tucker EM, Mathiasson ME, Rehan SM	Decline of bumble bees in northeastern North America with special focus on Bombus terricola	2017	Biological Conservation	217	n/a	437-455	USA	declines and distributions	pollinator declines, bee conservation, museum data, conservation status, species range, Bombus terricola
Jepsen S, Evans E, Thorp R, Hatfield R, Hoffman Black S	Petition to list: the rusty patched bumble bee *Bombus affinis* (Cresson), 1863 as an endangered species under the U.S. Endangered Species Act	2013	n/a	n/a	n/a	n/a	USA	declines and distributions	[none]
Kearns CA, Oliveras DM, Lay CR	Monitoring the conservation status of bumble bee populations across an elevation gradient in the Front Range of Colorado	2017	Journal of Insect Conservation	n/a	n/a	DOI 10.1007/s10841-017-9954-6	USA	declines and distributions	bumble bees, Bombus, pollinators, pollinator declines, pollinator monitoring
Kent CF, Dey A, Patel H, Tsvetlov N, Tiwari T, MacPhail VJ, Gobeil Y, Harpur BA, Gurtowski J, Schatz MC, Colla SR, Zayed A	Conservation genomics of the declining North American bumblebee Bombus terricola reveals inbreeding and selection on immune genes	2018	Frontiers in Genetics	9	n/a	doi: 10.3389/fgene.2018.00316	UK	declines and distributions	Bombus, bumblebee, conservation, inbreeding, pathogen, genomics, population genetics
Koch JB, Lozier J, Strange JP, Ikerd H, Griswold T, Cordes N, Solter L, Stewart I, Cameron SA	USBombus, a database of contemporary survey data for North American bumble bees (Hymenoptera, Apidae, Bombus) distributed in the United States	2015	Biodiversity Data Journal	3	n/a	e6833	USA	declines and distributions	[database, online data repository]
Kosior A, Celary W, Olejniczak P, Fijat J, Krol W, Solarz W, Plonka P	The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and Central Europe	2007	Oryx	41	1	79-88	Poland	declines and distributions	agriculture, Apidae, bees, Bombini, Bombus, Europe, Hymenoptera, pollinator loss, Psithyrus, threats

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Kremen C, Ricketts T	Global perspectives on pollination disruptions	2000	Conservation Biology	14	5	1226-1228	USA	declines and distributions	conservation
KW, Cariveau D, May E, Roswell M, Vaughan M, Williams N, Winfree R, Isaacs R, Gill K	Streamlined Bee Monitoring Protocol for Assessing Pollinator Habitat	2014	n/a	n/a	n/a	16	USA	declines and distributions	[none]
LaBerge WE, Webb MC	The bumblebees of Nebraska	1962	University of Nebraska Research Bulletin	205	n/a	n/a	USA	declines and distributions	[none]
Lozier JD, Cameron SA	Comparative genetic analyses of historical and contemporary collections highlight contrasting demographic histories for the bumble bees	2009	Molecular Ecology	18	n/a	1875-1886	USA	declines and distributions	Apidae, ancient DNA, conservation, Hymenoptera, natural history collections, pollinator decline
Maebe K, Meeus I, Ganne M, De Meuelemeester T, Beismeijer K, Smagghe G	Microsatellite analysis of museum specimens reveals historical differences in genetic diveristy between declining and more stable	2015	PLoS ONE	10	6	e0127870	Belgium	declines and distributions	[microsatellite, Bombus genetic diversity, declining species, stable species, Europe]
Magdich M	Bumble Bee Monitoring	2015	Wild Toledo Annual Report	2	n/a	31-33	USA	declines and distributions	[none]
McArt SH, Urbanowicz C, McCoshum S, Irwin RE, Adler LS	Landscape predictors of pathogen prevalence and range contractions in US bumblebees	2017	Proceedings of the Royal Society B	284	n/a	e20172181	USA	declines and distributions	[range contraction, bumble bee decline, USA, fungicide exposure, landscape, Nosema bombi]
Medler JT, Carney DW	Bumble bees of Wisconsin (Hymenoptera: Apidae)	1963	University of Wisconsin Research Bulletin	240	n/a	47	USA	declines and distributions	[none]
Meeus I, Brown MJF, DeGraaf DC, Smagghe G	Effects of invasive parasites on bumble bee declines	2011	Conservation Biology	25	4	662-671	Belgium	declines and distributions	Bombus, commercial rearing, pathogen spillover, protozoan parasites, viruses
Morales CL, Arbetman MP, Cameron SA, Aizen MA	Rapid ecological replacement of a native bumble bee by invasive species	2013	Frontiers in Ecology and the Environment	11	10	529-534	Argentina	declines and distributions	[Patagonia, South America, invasive species, Bombus]
Murray TE, Kuhlmann M, Potts SG	Conservation ecology of bees: populations, species, and communities	2009	Apidologie	40	n/a	211-236	Ireland	declines and distributions	conservation, biodiversity, population, community, plant-pollinator
Plath OE	Notes on the nesting habits of some of the less common New England bumblebees	1927	Pysche	34	n/a	122-128	USA	declines and distributions	[none]
Plath OE	Notes on the nesting habits of several North American bumblebees	1922	Pysche	29	n/a	189-202	USA	declines and distributions	[none]
Ploquin EF, Herrera JM, Obeso JR	Bumblebee community homogenization after uphill shifts in montane areas of northern Spain	2013	Oecologia	173	n/a	1649-1660	Spain	declines and distributions	Bombus spp, elevation, global change, lower boundary, upper boundary
Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE	Global pollinator declines: trends, impacts and drivers	2010	Trends in Ecology & Evolution	25	6	345-353	England	declines and distributions	colony collapse disorder, animal mutualistic networks, small hive beetle, honey-bees, apis-mellifera, habitat fragmentation, pollen limitation, crop pollination, aethina-tumida, bumble bees

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Richardson LL, McFarland KP, Zahendra S, Hardy S	Bumble bee (Bombus) distribution and diversity in Vermont, USA: A century of change	2018	Journal of Insect Conservation	[online]	n/a	https://doi.org/10.1007/s10841-018-0113-5	USA	declines and distributions	land use, conservation, citizen science, pollinator declines, Vermont
Roulston TH, Goodell K	The role of resources and risks in regulating wild bee populations	2011	Annual Review of Entomology	56	n/a	293-312	USA	declines and distributions	megachile-rotundata, hymenoptera, bombus-impatiens hymenoptera, plant-pollinator communities, bumble bee, nosema-bombi, native bees, landscape context, floral resources, solitary bees
Szymanski J, Smith T, Horton A, Parkin M, Ragan L, Masson G, Olson E, Gifford K, Hill L	Rusty Patched Bumble Bee (Bombus affinis) Species Status Assessment	2016	n/a	n/a	n/a	n/a	USA	declines and distributions	[none]
Tripodi AD, Szalanski AL	The bumble bees (Hymenoptera: Apidae: Bombus) of Arkansas, fifty years later	2015	Journal of Melittology	50	n/a	17-Jan	USA	declines and distributions	[Bombus decline, Arkansas, field survey, seasonal phenology, plant preferences]
Tucker EM, Rehan SM	High elevation refugia for *Bombus terricola* (Hymenoptera: Apidae) conservation and wild bees of the White Mountain National Forest	2017	Journal of Insect Science	17	1	01-010	USA	declines and distributions	Apodiea, species of greatest conservation need, biodiversity, New England, New Hampshire
USFWS Department of Interior	Conservation Management Guidelines for the Rusty Patched Bumble Bee (Bombus affinis). Version 1.6	2018	n/a	n/a	n/a	n/a	USA	declines and distributions	[none]
USFWS Department of Interior	Endangered and Threatened Wildlife and Plants; Endangered Species Status for Rusty Patched Bumble Bee	2017	Federal Register	82	7	3186-3209	USA	declines and distributions	[none]
USFWS Department of Interior	Rusty Patched Bumble Bee (Bombus affinis) Plants Favored by Rusty Patched Bumble Bee	2018	USFWS Endangered Species	n/a	n/a	n/a	USA	declines and distributions	[none]
Vanbergen AJ, Insect Pollinator Initiative	Threats to an ecosystem service: pressures on pollinators	2013	Frontiers in Ecology and the Environment	11	5	251-259	UK	declines and distributions	honeybee- health, apis-mellifera, pesticide exposure, climate-change, colony losses, native bees, bumble-bees, conservation, nosema, landscape
Warriner MD	Bumblebees (Hymenoptera: Apidae_ of remnant grasslands in Arkansas	2011	Journal of the Kansas Entomological Society	84	1	43-50	USA	declines and distributions	Bombus, conservation, diversity, extipration, regional fauna, species persistence
Wheeler WM	Review: The Humble-Bee, its Life History and How to Domesticate it, with Descriptions of All the British Species of Bombus and Psithyrus	1913	Science	37	944	180-182	UK	declines and distributions	[none]
Williams P, Colla S, Xie Z	Bumblebee vulnerability: common correlates of winners and losers across three continents	2009	Conservation Biology	23	4	931-940	UK	declines and distributions	bombus, climate specialization, community structure, faunal change, pollinator decline, species assemblages, species competition, species' vulnerability
Williams P, Jepsen S	Bumblebee specialist group report 2014	2014	IUCN Bumble Bee Specialist Group	n/a	n/a	1-15	UK	declines and distributions	[species extinction risk, worldwide status of bumble bee species, global assessment]
Williams P, Thorp R, Richardson L, Colla S	An Identification Guide: Bumble Bees of North America	2014	n/a	n/a	n/a	n/a	UK	declines and distributions	[none]

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Williams PH	The distribution and decline of British bumble bees (Bombus Latr.)	1982	Journal of Apictultural Research	21	4	236-245	UK	declines and distributions	[Bombus community composition, distribution, species range, range contraction, britain]
Williams PH	Environmental change and the distribution of British bumble bees (Bombus Latr)	1986	Bee World	67	2	50-61	England	declines and distributions	[none]
Williams PH	An annotated checklist of bumble bees with an analysis of patterns of description (Hymenoptera: Apidae, Bombini)	1998	Bulletin of the Natural History Museum Entomology	67	1	79-152	England	declines and distributions	[none]
Williams PH, Araujo MB, Rasmont P	Can vulnerability among British bumblebee (Bombus) species be explained by niche position and breadth?	2007	Biological Conservation	138	n/a	493-505	UK	declines and distributions	biodiversity loss, climate, niche, species assemblages, community structure, faunal change
Williams PH, Osborne JL	Bumblebee vulnerability and conservation world-wide	2009	Apidologie	40	n/a	367-387	UK	declines and distributions	bumblebee, Bombus, threat, vulnerability, decline, conservation
Kleijn D, Raemakers I	A retrospective analysis of pollen host plant use by stable and declining bumble bee species	2008	Ecology	89	7	1811-1823	Netherlands	declines and distributions, flower resource use	Bombus spp, ecosystem serviecs, food preference, foraging behavior, historical collections, invasive plants, land use change, pollination, rare species
Scheper J, Reemer M, van Kats R, Ozinga WA, van der Linden GTJ, Schaminee JHJ, Siepel H, Kleijn D	Museum specimens reveal loss of pollen host plants as key factor driving wild bee decline in the Netherlands	2014	Proceedings of the National Academy of Science	111	49	17552-17557	Netherlands	declines and distributions, flower resource use	bee decline, land use change, floral resources, pollen preference, crop pollination
Fitzpatrick U, Murray TE, Paxton RJ, Breen J, Cotton D, Santorum V, Brown MJF	Rarity and decline in bumblebees - a test of causes and correlates in the Irish fauna	2007	Biological Conservation	136	n/a	185-194	UK	declines and distributions, habitat	Bombus, biodiversity loss, species richness, decline
Grixti JC, Wong LT, Cameron SA, Favret C	Decline of bumble bees (Bombus) in the North American Midwest	2009	Biological Conservation	142	n/a	75-84	Canada	declines and distributions, habitat	pollinator decline, bee conservation, species richness, biodiversity, museum data, Hymenoptera database
Steffan-Dewenter I, Westphal C	The interplay of pollinator diversity, pollination services and landscape change	2008	Journal of Applied Ecology	45	n/a	737-741	Germany	declines and distributions, habitat	agri-environment schemes, bees, butterflies, ecosystem services, gene flow, habitat fragmentation, habitat management, land use intensification, spatial scales
Barlow SE, Wright GA, Ma C, Barberis M, Farrell IW, Marr EC, Brankin A, Pavlik B, Stevenson PC	Distasteful nectar deters floral robbery	2017	Current Biology	27	n/a	2552-2558	UK	flower resource use	[toxic nectar, nectar robbery, plant defense, mutualism, Aconitum, Bombus]
Bernhardt CE	Effect of *Lupinusperennis* population size and local density on pollinator behavior	2000	MS thesis, University of Akron	n/a	n/a	n/a	USA	flower resource use	[lupine pollination, population size, pollinator behavior]
Bernhardt CE, Mitchell RJ, Michels HJ	Effects of population size and density on pollinator visitation, pollinator behavior, and pollen tube abundance in Lupinus perennis	2008	International Journal of Plant Sciences	169	7	944-953	USA	flower resource use	Bombus, Fabaceae, conservation, plant-pollinator interactions, pollination, Osmia
Brian AD	The pollen collected by bumble-bees	1951	Journal of Animal Ecology	20	2	191-194	UK	flower resource use	[Bombus, nests, pollen use, Scotland]

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Carvell C, Westrich P, Meek WR, Pywell RF, Nowakowski M	Assessing the value of annual and perennial forage mixtures for bumblebees by direct obsrvation and pollen analysis	2006	Apidologie	37	n/a	326-340	UK	flower resource use	bumblebees, foraging, pollen, seed mixture, restoration, Bombus
Cresswell JE, Osborne JL, Goulson D	An economic model of the limits to foraging range in central place foragers with numerical solutions for bumblebees	2000	Ecological Entomology	25	n/a	249-255	UK	flower resource use	Bombus, central place foraging, energetics, flight range
Dornhaus A, Chittka L	Information flow and regulation of foraging activity in bumble bees (Bombus spp.)	2004	Apidologie	35	n/a	183-192	Germany	flower resource use	Bombus terrestris, recruitment, social insect, collective foraging, communication
Dornhaus A, Chittka L	Food alert in bumblebees (Bombus terrestris): Possible mechanisms and evolutionary implications	2001	Behavioral Ecology and Sociobiology	50	n/a	570-576	Germany	flower resource use	communication, pheromone, foraging, bee dance, recruitment
Dramstad W, Fry G	Foraging activity of bumblebees (Bombus) in relation to flower resources on arable land	1995	Agriculture, Ecosystems and Environment	53	n/a	123-135	Norway	flower resource use	bumblebees, farmland, foraging, field margins, floral resources
Dramstad WE	Do bumblebees (Hymenoptera: Apidae) really forage close to their nests?	1996	Journal of Insect Behavior	9	2	163-182	Norway	flower resource use	bumblebees (Bombus), flight distances, foraging behavior
Dramstad WE, Fry GLA, Schaffer MJ	Bumblebee foraging - is closer really better?	2003	Agriculture, Ecosystems and Environment	95	n/a	349-357	Norway	flower resource use	bumblebees, flight distance, foraging, Phacelia
Drossart M, Michez D, Vanderplanck M	Invasive plants as potential food resource for native pollinators: A case study with two invasive species and a generalist bumble bee	2017	Nature Scientific Reports	7	n/a	16242	Belgium	flower resource use	[invasive plants, amino acid composition of pollen, Bombus terrestris, Europe, colonies, foragers, visitation rate, pollen load weight]
Fussell M	Diurnal patterns of bee activity, flowering, and nectar reward per flower in tetraploid red clover	1992	New Zealand Journal of Agricultural Research	35	2	151-156	UK	flower resource use	red clover, pollination, long-tongued bumble-bees, Bombus hortorum, foraging, ncetar rewards, honey-bees
Fussell M, Corbet SA	Flower usage by bumble-bees: A basis for forage plant management	1992	Journal of Applied Ecology	29	n/a	451-465	UK	flower resource use	bumble-bees, selectivity, flower visits, pollination, succession
Galen C, Stanton ML	Bumble bee pollination and floral morphology: Factors influence pollen dipspersal in the alpine sky pilot, Polemonium viscosum (Polemoniaceae)	1989	American Journal of Botany	76	3	419-426	USA	flower resource use	[Polemonium, alpine meadow, pollen donor, recipient, flower size, outcross pollen]
Gillespie SD, Bayley J, Elle E	Native bumble bee (Hymenoptera: Apidae) pollinators vary in floral resource use across an invasion gradient	2017	The Canadian Entomologist	149	n/a	204-213	Canada	flower resource use	[invasive plants, plant-pollinator networks, habitat fragmentation, native pollinators, Apis mellifera, Bombus, Cytisus scoparius]
Goulson D, Darvill B	Niche overlap and diet breadth in bumblebees: Are rare species more specialized in their choice of flowers?	2004	Apidologie	35	n/a	55-63	UK	flower resource use	Hymenoptera, Bombus, rarity, tongue length, pollen, competition
Goulson D, Lye GC, Darvill B	Diet breadth, coexistence and rarity in bumblebees	2008	Biodiversity and Conservation	17	n/a	3269-3288	UK	flower resource use	Hymenoptera, Bombus, community composition, forage use, tongue length, pollen, competition

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Jha A, Stefanovish L, Kremen C	Bumble bee pollen use and preference across spatial scales in human-altered landscapes	2013	Ecological Entomology	38	n/a	570-579	USA	flower resource use	agriculture, ecosystem service, foraging behavior, pollinator, resource dynamics
Kawaguchi LG, Ohashi K, Toquenaga Y	Do bumble bees save time when choosing novel flowers by following conspecifics?	2006	Functional Ecology	20	n/a	239-244	Japan	flower resource use	Bombus terrestris, foraging behaviour, information transfer, local enhancement, plant-animal interactions
Kells AR, Holland JM, Goulson D	The value of uncropped field margins for foraging bumblebes	2001	Journal of Insect Conservation	5	n/a	283-291	UK	flower resource use	agriculture, Apis mellifera, Bombus, floral resources, naturally regenerated field margin
Kitaoka TK, Nieh HC	Manuscript in preparation for Behavioral Ecology and Sociobiology Bumble be pollen foraging regulation: role of pollen quality, storage	2009	Behavioral Ecology and Sociobiology	63	n/a	501-510	USA	flower resource use	communication, recruitment, foraging, information flow, collective behavior, social insect
Leadbeater E, Chittka L	A new mode of information transfer in foraging bumblebees?	2005	Current Biology	15	12	R448	Belgium	flower resource use	[none]
Macior LW	Pollen-foraging behavior of Bombus in relatino to pollination of nototribic flowers	1967	American Journal of Botany	54	3	359-364	USA	flower resource use	[Bombus pollen deposition, nototribic flowers, foraging, pollen collecting behavior, bee morphology]
Mola JM, Williams NM	Fire-induced change in floral abundance, density, and phenology benefits bumble bee foragers	2018	Ecosphere	9	1	e02056	USA	flower resource use	bumble bees, disturbance, fire, flowering, interspecific interactions, phenology, pollinators, seasonality
Molet M, Chittka L, Raine NE	How floral odours are learned inside the bumblebee (Bombus terrestris) nest	2009	Naturwissenschaften	96	n/a	213-219	UK	flower resource use	floral scent, foraging recruiment pheromone, honeypot, memory, social learning
Molet M, Chittka L, Stelzer RJ, Streit S, Raine NE	Colony nutrional status modulates worker responses to foraging recruitment pheromone in the bumblebee Bombus terrestris	2008	Behavioral Ecology and Sociobiology	62	n/a	1919-1926	UK	flower resource use	activity pettern, context dependence, cue, feedback, honeypot, signal, social insect
Motten AF	Pollination ecology of the spring wildflower community of a temperate deciduous forest	1986	Ecological Monographs	56	1	21-42	USA	flower resource use	bees, Bombylius major, competition, deciduous forest, floral biology, forest herbs, North Carolina, plant community, pollination, seed-set, spring wildflowers
Munidasa DT, Toquenaga Y	Do pollen diets vary among adjacent bumble bee colonies?	2010	Ecological Research	25	n/a	639-646	Japan	flower resource use	bumble bee, foraging range, intraspecific, small-scale landscape, work force
Ogilvie JE, Griffin SR, Gezon ZJ, Inouye BD, Underwood N, Inouye DW, Irwin RE	Interannual bumble bee abundance is driven by indirect climate effects on floral resource phenology	2017	Ecology Letters	20	n/a	1507-1515	USA	flower resource use	bumble bee, Bombus, climate change, floral resources, phenology, pollinator, precipitation, snowmelt, structural equation model
Osborne JL, Martin AP, Carreck NL, Swain JL, Knight ME, Goulson D, Hale RJ, Sanderson RA	Bumblebee flight distances in relation to the forage landscape	2008	Journal of Animal Ecology	77	n/a	406-415	UK	flower resource use	borage, foraging range, mass marketing experiment, pollen analysis
Pope NS, Jha S	Seasonal food scarcity prompts long-distance foraging by a wild social bee	2018	The American Naturalist	191	1	45-57	USA	flower resource use	bumblebee, dispersal, phenology, pollination, spatial ecology
Prusnek SC	Nectar robbing and pollination ecology of the spring ephemeral, Mertensia virginica (Boraginaceae)	1999	MS Thesis, University of Akron	n/a	n/a	n/a	USA	flower resource use	[bumble bee queen pollination, spring epheremal wildflowers, bluebells, B.affinis, B.ashtoni]

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Rasheed SA, Harder LD	Economic motivation for plant species preferences of pollen-collecting bumble bees	1997	Ecological Entomology	22	n/a	209-219	Canada	flower resource use	Bombus, pollen collection, preference, protein, currency
Redhead JW, Dreier S, Bourke AFG, Heard MS, Jordan WC, Sumner S, Wang J, Carvell C	Effects of habitat composition and landscape structure on worker foraging distances of five bumble bee species	2016	Ecological Applications	26	3	726-739	UK	flower resource use	agri-environment, Bombus, foraging range, landscape scale, pollination, spatial ecology, wild colonies
Saifuddin M, Jha S	Colony-level variation in pollen collection and foraging preferences among wild-caught bumble bees (Hymenoptera: Apidae)	2014	Environmental Entomology	43	2	393-401	USA	flower resource use	foraging behavior, pollinator, *Bombus,* bumble bee, pollen
Spaethe J, Weidenmuller A	Size variation and foraging rate in bumblebees (Bombus terrestris)	2002	Insectes Sociaux	49	n/a	142-146	Germany	flower resource use	bumblebees, size polymorphism, foraging behavior, nectar loads, division of labor, interindividual variability
Stelzer RJ, Chittka L	Bumblebee foragiing rhythms under the midnight sun measured with radiofrequency identification	2010	BMC Biology	8	n/a	93	UK	flower resource use	[arctic circle, diurnal rhythms, foraging, Bombus terrestris, Bombus pascuourum, circadian rhythm]
Thomson JD	Pollen transport and deposition by bumblebees in Erythronium: Influences of floral nectar and bee grooming	1986	Journal of Ecology	74	n/a	329-341	USA	flower resource use	[pollen transport, deposition, Erythronium, spring wildflower pollination, bee grooming, Bombus, bumble bee queen]
Walther-Hellwisg K, Frankl R	Foraging habitats and foraging distances of bumblebees, Bombus spp. (Hym., Apidae), in an agricultural landscape	2000	Journal of Applied Entomology	124	n/a	299-306	Germany	flower resource use	[agriculture, flower visits, landscape, community structure, bumble bees, mark-recapture]
Woodgate JL, Makinson JC, Lim KS, Reynolds AM, Chittka L	Life-long radar tracking of bumblebees	2016	PLoS ONE	11	8	e0160333	UK	flower resource use	[none]
Worden BD, Papaj DR	Flower choice copying in bumblebees	2005	Biology Letters	1	n/a	504-507	USA	flower resource use	bumblebees, social learning, stimulus enhancement, social information
Kreyer D, Oed A, Walther-Hellwig K, Frankl R	Are forests potential landscape barriers for foraging bumblebees? Landscape scale experiments with Bombus terrestris agg. And Bombus pascuourum (Hymenoptera: Apidae)	2004	Biological Conservation	116	n/a	111-118	Germany	flower resource use, habitat	pollen flow, home range, habitat fragmentation, foraging behaviour, pollinator movement
Pardee GL, Philpott SM	Native plants are the bee's knees: Local and landscape predictors of bee richness and abundance in backyard gardens	2014	Urban Ecosystems	17	3	641-659	USA	flower resource use, habitat	native bees, urban gardens, Hymenoptera, pollination, urbanization
Schmid-Hempel P, Durrer S	Parasites, floral resources and reproduction in natural populations of bumblebees	1991	Oikos	62	3	342-350	Switzerland	flower resource use, nesting / reproduction	[flower availability, Conopid fly parasitism, colony reproduction]
Westphal C, Steffan-Dewenter I, Tscharntke T	Foraging trip duration of bumblebees in relation to landscape-wide resource availability	2006	Ecological Entomology	31	n/a	389-394	Germany	flower resource use, nesting / reproduction, habitat	agroecosystems, Bombus terrestris, colony growth, conservation, landscape structure, large-scale resource availability, Phacelia tanacetifolia, pollination
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. III. Subgenus *Cullumanobombus* Vogt	1965	The Canadian Entomologist	97	n/a	1293-1302	Canada	general	[none]

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Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. II. Subgenus *Bombias* Robt.	1965	The Canadian Entomologist	97	n/a	120-128	Canada	general	[none]
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. V. Subgenus *Subterraneobombus* Vogt	1966	The Canadian Entomologist	98	n/a	288-294	Canada	general	[none]
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. IV. Subgenus *Fervidobombus* Skorikov	1966	The Canadian Entomologist	98	n/a	33-39	Canada	general	[none]
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta.VI. Subgenus *Pyrobombus*	1967	The Canadian Entomologist	99	n/a	1271-1292	Canada	general	[none]
Hobbs GA	Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta.VII. Subgenus *Bombus*	1968	The Canadian Entomologist	100	n/a	156-164	Canada	general	[none]
Hobbs GA, Nummi WO, Virostek JF	Managing colonies of bumble bees (Hymenoptera: Apidae) for pollination purposes	1962	The Canadian Entomologist	94	11	1121-1132	Canada	general	[none]
Macfarlane RP	Ecology of Bombinae (Hymenoptera: Apidae) of southern Ontario, with emphasis on their natural enemies and relationships with flowers	1974	PhD thesis, University of Guelph	n/a	n/a	n/a	Canada	general, nesting / reproduction, flower resource use	[foraging, nest initiation, flight period, natural history, ovary maturation, queen fat body depletion, nest parasites]
Darvill B, Knight ME, Goulson D	Use of genetic markers to quantify bumblebee foraging range and nest density	2004	Oikos	107	n/a	471-478	UK	genetics	none
Dreier S, Redhead JW, Warren IA, Bourke AFG, Heard MS, Jordan WC, Sumner S, Wang J, Carvell C	Fine-scale spatial genetic structure of common and declining bumble bees across an agricultural landscape	2014	Molecular Ecology	23	n/a	3384-3395	UK	genetics	Bombus, conservation, isolation by distance, microsatellite, queen dispersal, related- ness
Herrmann F, Westphal C, Moritz RFA, Steffan-Dewenter I	Genetic diversity and mass resources promote colony size and forager densities of a social bee (Bombus pascuourum) in agricultural landscapes	2007	Molecular Ecology	16	n/a	1167-1178	Germany	genetics	bumblebees,inbreedingcoefficient,landscapestructure,massfloweringcrops,pollinators, population genetics, population size
Knight ME, Osborne JL, Sanderson RA, Hale RJ, Martin AP, Goulson D	Bumblebee nest density and the scale of available forage in arable landscapes	2009	Insect Conservation and Diversity	2	n/a	116-124	UK	genetics	*Bombus pascuorum* , forage availability, foraging range, kinship, mass flowering crops, microsatellites, nest density
Lepais O, Darvill B, O'Connor S, Osborne JL, Sandeson RA, Cussans J, Goffe L, Goulson D	Estimate of bumblebee queen dispersal distances using sibship reconstruction method	2010	Molecular Ecology	19	n/a	819-831	UK	genetics	Bombus, kinship, microsatellite, population structure, social insects
Lozier J, Strange J, Stewarts IJ, Cameron S	Patterns of range-wide genetic variation in six North-American bumble bee (Apidae: Bombus) species	2011	Molecular Ecology	20	n/a	4870-4888	USA	genetics	allelic richness, conservation, heterozygosity, microsatellites, pollinators, population structure
Carvell C, Bourke AFG, Dreier S, Freeman SN, Hulmes S, Jordan WC, Redhead JW, Sumner S, Wang J, Heard MS	Bumblebee family linear survival is enhanced in high-quality landscapes	2017	Nature	543	7646	547-549	UK	genetics, habitat	agri-environment shemes, colony growth, bombus-terrestris, marked animals, land-use, bees, pollinators, habitat, conservation, resources

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Goulson D, Lepais O, O'Connor S, Osborne J, Sanderson RA, Cussans J, Goffe L, Darvill B	Effects of land use at a landscape scale on bumblebee nest density and survival	2010	Journal of Applied Ecology	47	n/a	1207-1215	UK	genetics, habitat	Bombus, density, gardens, kinship, microsatellite, mortality, pollination services, population structure, social insects
Ahrne K, Bengtsson J, Elmqvist T	Bumble Bees (*Bombus* spp) along a Gradient of Increasing Urbanization	2009	PLoS ONE	4	5	[online]	Sweden	habitat	[none]
Banaszak-Cibicka W, Żmihorski M	Wild bees along an irban gradient: winners and losers	2011	Journal of Insect Conservation	16	3	331-343	Poland	habitat	Hymenoptera, Apoidea, Bees, Urbanization, City, Poznán
Bates AJ, Sadler JP, Fairbrass AJ, Falk SJ, Hale JD, Matthews TJ	Changing bee and hoverfly pollinator assemblages along and urban-rural gradient	2011	PLoS ONE	6	8	[online]	UK	habitat	[none]
Bhattacharya M, Primack RB, Gerwein J	Are roads and railroads barriers to bumblebee movement in a temperate suburban conservation area?	2003	Biological Conservation	109	n/a	37-45	USA	habitat	habitat fragmentation, bumblebees, bombus, clethra anifolia, anthropogenic barriers, pollination
Carvell C	Habitat use and conservation of bumblebees (Bombus spp.) under different grassland management regimes	2002	Biological Conservation	103	n/a	33-49	UK	habitat	bumblebees, Bombus, foraging, habitat characteristics, Chalk grassland, grazing
Carvell C, Meek WR, Pywell RF, Goulson D, Nowakowski M	Comparing the efficacy of agri-environment schemes to enhance bumble bee abundance and diversity on arable field margins	2007	Journal of Applied Ecology	44	n/a	29-40	UK	habitat	agri-environment, arable farmland, Bombus, bumblebees, forage plants
Carvell C, Osborne JL, Bourke AFG, Freeman SN, Pywell RF, Heard MS	Bumble bee species' responses to a targeted conservation measure depend on landscape context and habitat quality	2011	Ecological Applications	21	5	1760-11771	UK	habitat	agri-environment schemes, bee conservation, Bombus spp., forage plants, habitat quality, land use, pollinators, United Kingdom
Fortel L, Henry M, Guilbaud L, Guirao AL, Kuhlmann M, Mouret H, Rollin O, Vaissiere BE	Decreasing abundance, increasing diversity, and changing structure of the wild bee community (Hymenoptera: Anthophila) along an urbanization gradient	2014	PLoS ONE	9	8	[online]	France	habitat	[none]
Glaum P, Simao MC, Vaidya C, Fitch G, Iulinao B	Big city *Bombus* : using natural history and land-use history to find significant environmental drivers in bumble-bee declines in urban development	2017	Royal Society Open Science	4	n/a	[online]	USA	habitat	urbanization, pollinator, geographical information system, shrinking city, *Bombus*
Hatfield RG, LeBuhn G	Patch and landscape factors shape community assemblage of bumble bees, Bombus spp. (Hymenoptera: Apidae), in montane meadows	2007	Biological Conservation	139	n/a	150-158	USA	habitat	Sierra Nevada, patch, landscape, scale, grazing, pollinator
Heard MS, Carvell C, Carreck NL, Rothery P, Osborne JL, Bourke AFG	Landscape context not patch size determines bumble-bee density on flower mixtures sown for agri-environment schemes	2007	Biological Letters	3	6	638-641	UK	habitat	*Bombus,* forage plants, pollination
Hendrickx F, Maelfait JP, Wingerden WV, Schweiger O, Speelmans M, Aviron S, Augenstein I, Billeter R, Bailey D, Bukacek R, Burel F, Diekötter T, Dirksen J, Herzog F, Liira J, Roubalova M, Vandomme V, Bugter R	How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes	2007	Journal of Applied Ecology	44	n/a	340-351	Belgium	habitat	agro-ecosystems, biodiversity, conservation, diversity partitioning, fragmentation, insects, landscape ecology

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Hopwood JL	the contribution of roadside grassland restorations to native bee conservation	2008	Biological Conservation	141	n/a	2632-2640	USA	habitat	Apoidea, ecosystem services, pollinators, prairie plants, vegetation management
Hopwood JL	Roadsides as habitat for pollinators: Management to support bees and butterflies	2013	Proceedings of the International Conference on Ecology and Transportation	n/a	n/a	n/a	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat]
Hulsmann M, vonWehrden H, Klein AM, Leonhardt SD	Plant diversity and composition compensate for negative effects of urbanization on foraging bumble bees	2015	Apidologie	46	6	760-770	Germany	habitat	bee decline, habitat fragmentation, Hymenoptera, pollination, urban landscape
Jha A, Kremen C	Urban land use limits regional bumble bee gene flow	2013	Molecular Ecology	22	n/a	2483-2495	USA	habitat	*Bombus* , dispersal, landscape genetics, microsatellites, pollinator, urban ecology
Johnson AL, Fetters AM, Ashman T-L	Considering the unintentional consequences of pollinator gardens for urban native plants: is the road to extinction paved with good	2017	New Phytologist	215	4	[online]	USA	habitat	biodiversity, conservation biology, native plants, pollination, pollinator, restoration, urban ecology
Kamper W, Weiner C, Kuhsel S, Storm C, Eltz T, Bluthgen N	Evaluating the effects of floral resource specialisation and of nitrogen regulation on the vulnerability of social bees in agricultural landscapes	2017	Apidologie	48	n/a	371-383	Germany	habitat	resource specialisation, pollinator, land-use response, homeostasis, biodiversity
Koh I, Londsdorf EV, Williams NM, Brittain C, Isaacs R, Gibbs J, Ricketts TH	Modeling the status, trends, and impacts of wild bee abundance in the United States	2016	Proceedings of the National Academy of Science	113	1	140-145	USA	habitat	crop pollination, ecosystem services, habitat suitability, land-use change, uncertainty
McFredrick QS, LeBuhn G	Are urban parks refuges for bumble bees *Bombus* spp. (Hymenoptera: Apidae)?	2006	Biological Conservation	129	3	372-382	USA	habitat	*Bombus,* urban parks, San Francisco, matric, nest sites
Minnesota Department of Transportation	Partnerships for promoting pollinator habitat	2016	MN DOT bulletin	n/a	n/a	TRS1601	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat, commnity partnerships]
Ohio Department of Transportation, Ohio Pollinator Habitat Initative	Saving Ohio's pollinators: Bee pollinator habitat planting guidelines. District 9	n/a	ODOT bulletin	n/a	n/a	n/a	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat]
Ohio Department of Transportation, Ohio Pollinator Habitat Initative	Statewide roadside pollinator habitat program restoration guidelines and best management practices	2016	n/a	n/a	n/a	n/a	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat]
Russell KN, Ikerd H, Droege S	The potential conservation value of unmowed powerline strips for native bees	2005	Biological Conservation	124	n/a	133-148	USA	habitat	native bees, powerline coridors, right-of-ways, vegetation management, species richness, nesting habitat
Samuelson AE, Leadbeater E	A land classification protocol for pollinator ecology research: an urbanization case study	2018	Ecology and Evolution	[online]	n/a	13-Jan	UK	habitat	agricultural pest control, anthropogenic stressors, bees, GIS, land classification, land-use change, pollinator, urbanization
Schochet AB, Hung KLJ, Holway DA	Bumble bee species exhibit divergent responses to urbanisation in a Southern California landscape	2016	Ecological Entomology	41	n/a	685-692	USA	habitat	Apoidea, *Bombus,* GIS, pollinator, spatial scale

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Senapathi D, Carvalheiro LG, Biesmeijer JC, Dodson CA, Evans RL, McKerchar M, Morton RD, Moss ED, Roberts SPM, Kunin WE, Potts SG	The impact of over 80 years of land cover changes on bee and wasp pollinator communities in England	2018	Royal Society B: Biological Sciences	[online]	n/a	n/a	UK	habitat	historical land cover change, pollinators, species richness, species composition
Sowig P	Effects of flowering plant's patch size on species composition of pollinator communities, foraging strategies, and resource partitioning in bumblebees (Hymenoptera: Apidae)	1989	Oecologia	78	n/a	550-558	Germany	habitat	bumblebees, patch size, foraging strategies, community structure, resource partitioning
Tscharntke T, Steffan-Dewenter I, Kruess A, Thies C	Characteristics of insect populations on habitat fragments: A mini review	2002	Ecological Research	17	n/a	229-239	Germany	habitat	conservation, landscape structure, reserve design, scale dependence, trophic interactions
Tscharntke T, Tylianakis JM, Rand TA, Didham RK, Fahrig L, Batary P, Bengtsson J, Clough Y, Crist TO, Dormann CF, Ewers RM, Frund J, Holt RD, Holzschuh A, Klein AM, Kleijn D	Landscape moderation of biodiversity patterns and processes - eight hypotheses	2012	Biological Reviews	87	n/a	661-685	Germany	habitat	beta diversity, belowground-aboveground patterns, conservation management, ecosystem functioning and services, functional traits, insurance hypothesis, landscape composition and
US Department of Transporation Federal Highway Administration	Pollinators and roadsides: Best management practices for managers and decision makers	2016	Federal Highway Administration bulletin	n/a	n/a	n/a	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat]
US Department of Transporation Federal Highway Administration	FHWA Encourages states to take action in achieving pollinator health	2015	Successes in Stewardship newsletter	Aug-15	n/a	n/a	USA	habitat	[seed mix, roadside grassland restoration, vegetation management, pollinator habitat]
Vogiatzakis IN, Stirpe MT, Rickebusch S, Metzger MJ, Xu G, Rounsevell MDA, Bommarco R, Potts SG	Rapid assessment of historic, current, and future habitat quality for biodiversity around UK Natura 2000 sites	2015	Environmental Conservation	42	1	31-40	UK	habitat	expert opinion, land use, monitoring, protected areas, scenario analysis
Westphal C, Steffan-Dewenter I, Tscharntke T	Bumblebees experience landscapes at different spatial scales: possible implications for coexistence	2006	Oecologia	149	n/a	289-300	Germany	habitat	*Bombus* spp., pollination, foraging ranges, coexistence, resource partitioning
Beckham JL, Atkinson S	An updated understanding of Texas bumble bee (Hymenoptera: Apidae) species presence and potential distributions in	2017	PeerJ	5	n/a	e3612	USA	habitat, declines and distributions	pollinators, species decline, conservation, species distribution modeling, MaxEnt modeling, Natural history collections, Citizen science data, bumble bees
Bommarco R, Biesmeijer JC, Meyer B, Potts SG, Poyry J, Roberts SPM, Steffan-Dewwenter I, Ockinger R	Dispsersal capacity and diet breadth modify the response of wild bees to habitat loss	2010	Proceedings of the Royal Society B	277	n/a	2075-2082	Sweden	habitat, declines and distributions	habitat fragmentation, pollinator, body size, resource specialisation, sociality, Bombus
Carvell C, Roy DB, Smart SM, Pywell RF, Preston CD, Goulson D	Declines in forage availability for bumblebees at a national scale	2006	Biological Conservation	132	n/a	481-489	UK	habitat, flower resource use	Bombus, forage plants, habitat quality, pollinators, conservation
Hines HM, Hendrix SD	Bumble bee (Hymenoptera: Apidae) diversity and abundance in tallgrass prairie patches: Effects of local and landscape floral resources	2005	Environmental Entomology	34	6	1477-1484	USA	habitat, flower resource use	fragmentation, pollination, bumblebee
Otto CRV, O'Dell S, Bryant RB, Euliss NH, Bush RM, Smart MD	Using publicly available data to quantify plant-pollinator interactions and evaluate conservation seeding mixes in the Northern Great Plains	2017	Environmental Entomology	46	3	565-578	USA	habitat, flower resource use	native bee, honey bee, forage, plant visit, seed mix
Saville NM, Dramstad WE, Fry GLA, Corbet SA	Bumblebee movement in a fragmented agricultural landscape	1997	Agriculture, Ecosystems and Environment	61	n/a	145-154	Nepal	habitat, flower resource use	bumblebees, mark-reobseration, movement, farmland

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Birmingham AL, Hoover SE, Winston ML, Ydenberg RC	Drifting bumble bee (Hymenoptera: Apidae) workers in commercial greenhouses may be social parasites	2004	Canadian Journal of Zoology	82	n/a	1843-1853	Canada	managed colonies	[none]
Alford DV	A study of the hibernation of bumblebees (Hymenoptera: Bombidae) in Southern England	1969	Journal of Animal Ecology	38	1	149-170	UK	nesting / reproduction	[bumble bee hibernation, habitat use, England]
Baron GL, Jansen VAA, Brown MJF, Raine NE	Pesticide reduces bumblebee colony initiation and increases probability of population extinction	2017	Nature	[online]	n/a		UK	nesting / reproduction	[pesticide exposure, queen nest initiation, neonicotinoid thiamethoxam, Crithidia bombi, hibernation]
Beekman M, Van Stratum P	Does the diapause experience of bumblebee queens Bombus terrestris affect colony characteristics?	2000	Ecological Entomology	25	n/a	6-Jan	Netherlands	nesting / reproduction	Bombusterrestris, bumblebees, colony characteristics, costs of diapause, diapause, nondiapause, trade-off
Beekman M, Van Stratum P, Veerman A	Selection for non-diapause in the bumblebee Bombus terrestris, with notes on the effect of inbreeding	1999	Entomologia Experimentalis et Applicata	93	n/a	69-75	Netherlands	nesting / reproduction	Bombus terrestris, bumblebees, (non-)diapause, bivoltism, inbreeding, isofemale lines
Bowers MA	Resource availability and timing of reproduction in bumble bee colonies (Hymenoptera: Apidae)	1986	Environmental Entomology	15	n/a	750-755	USA	nesting / reproduction	[onset of bumble bee reproduction, flower density, subalpine meadows]
Frison TH	Notes on Bombidae, and on the life history of Bombus auricomus Robt	1917	Annals of the Entomological Society of America	10	n/a	277-288	USA	nesting / reproduction	[none]
Frison TH	Additional notes on the life history of Bombus auricomus Robt	1918	Annals of the Entomological Society of America	11	n/a	43-49	USA	nesting / reproduction	[none]
Fussell M, Corbet SA	the nesting places of some British bumblebees	1992	Journal of Apicultural Research	31	1	32-41	UK	nesting / reproduction	Bombus, bumble bees, domiciles, habiat selection, nests, surveys, UK
Goulson D, O'Connor S, Park KJ	Causes of colony mortality in bumblebees	2018	Animal Conservation	21	n/a	45-53	UK	nesting / reproduction	[onset of bumble bee reproduction, queen production, nest destruction by flooding, animals, pests]
Harder LD	Influences on the density and dispersion of bumble bee nests (Hymenoptera: Apidae)	1986	Holarctic Ecology	9	2	99-103	USA	nesting / reproduction	[none]
Hobbs GA	Phylogeny of bumble bees based on brood-rearing behaviour	1964	The Canadian Entomologist	96	n/a	115-116	Canada	nesting / reproduction	[bumble bee nesting behavior, brood-rearing, egg laying, pocket makers versus pollen storers]
Kells AR, Goulson D	Preferred nesting sites of bumblebee queens (Hymenoptera: Apidae) in agroecosystems in the UK	2003	Biological Conservation	109	n/a	165-174	UK	nesting / reproduction	Bombus spp., nest searching, field boundary, forest boundary, tussock, bank
Knight ME, Martin AP, Bishop S, Osborne JL, Hale RJ, Sanderson RA, Goulson D	An interspecific comparison of foraging range and nest density of four bumblebee (Bombus) species	2005	Molecular Ecology	14	n/a	1811-1820	UK	nesting / reproduction	Bombus, foraging range, kinship, microsatellites, nest density
Lanterman J, Goodell K	Bumble bee colony growth and reproduction on reclaimed surface coal mines	2017	Restoration Ecology	26	1	183-194	USA	nesting / reproduction	bee forage, Bombus, floral resources, landscape, mine reclamation, pollinator conservation, pollinator habitat

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Lye G, Park K, Osborne J, Holland J, Goulson D	Assessing the value of Rural Stewardship schemes for providing foraging resources and nesting habitat for bumblebee queens	2009	Biological Conservation	142	n/a	2023-2032	UK	nesting / reproduction	Bombus, pollinator, agri-environment, land management, farm, agritculture
Lye GC, Osborne JL, Park KJ, Goulson D	Using citizen science to monitor Bombus populations in the UK: Nesting ecology and relative abundance in the urban environment	2012	Journal of Insect Conservation	16	n/a	697-707	UK	nesting / reproduction	Bombus spp., conservation, nest ecology, public outreach, species decline
Macior LW	Bombus (Hymenoptera, Apidae) queen foraging in relation to vernal pollination in Wisconsin	1968	Ecology	49	1	20-25	USA	nesting / reproduction	[none]
Mallinger RE, Werts R, Gratton C	Pesticide use within a pollinator-dependent crop has negative effects on the abundance and species richness of sweat bees, Lasioglossum spp, and on	2015	Journal of Insect Conservation	19	n/a	999-1010	USA	nesting / reproduction	toxicity, native bee, Bombus, apple orchard, pest management, organic
Medler JT	Development and absorption of eggs in bumblebees (Hymenoptera: Apidae)	1962	The Canadian Entomologist	94	n/a	825-833	USA	nesting / reproduction	[none]
O'Connor S, Park K, Goulson D	Location of bumblebee nests is predicted by counts of nest-searching queens	2017	Ecological Entomology	42	n/a	731-736	UK	nesting / reproduction	Apidae, Bombus, colony, floral resources, nest founding
O'Connor S, Park KJ, Goulson D	Humans versus dogs: A comparison of methods for the detection of bumble bee nests	2012	Journal of Apictultural Research	51	2	204-211	UK	nesting / reproduction	Bombus, nest density, nest location, public survey, detection dog
Pelletier L, McNeil JN	The effect of food supplementation on reproductive success in bumblebee field colonies	2003	Oikos	103	n/a	688-694	Canada	nesting / reproduction	[food availability, managed field colonies, B. impatiens, B. ternarius, colony reproduction]
Pomeroy N	Use of natural sites and field hives by a long-tongued bumble bee Bombus ruderatus	1981	New Zealand Journal of Agricultural Research	24	n/a	409-414	New Zealand	nesting / reproduction	bumble bee, Bombus ruderatus, Apinae, nests, hives, pollination, habitats, population density
Richards KW	Nest site selection by bumble bees (Hymenoptera: Apidae) in southern Alberta	1978	The Canadian Entomologist	110	n/a	301-318	Canada	nesting / reproduction	[none]
Roseler PF	A technique for year-round rearing of Bombus terrestris (Apidae, Bombini) colonies in captivity	1985	Apidologie	16	2	165-170	Germany	nesting / reproduction	[bumble bee queen, hibernation, carbon dioxide, induced egg-formation, colonies]
Rundlof M, Persson A, Smith HG, Bommarco R	Late-seasoning mass-flowering red clover increases bumble bee queen and male densities	2014	Biological Conservation	172	n/a	138-145	Sweden	nesting / reproduction	Bombus, flower resources, mitigation measure, pollinator, reproductive success, Trifolium pratense
Stanley DA, Raine NE	Bumblebee colony development following chronic exposure to field-realistic levels of neonicitinoid pesticide thiamethoxam under laboratory conditions	2017	Nature Scientific Reports	7	n/a	8005	UK	nesting / reproduction	[none]
Suzuki Y, Kawaguchi LG, Munidasa DT, Toquenaga Y	Do bumble bee queens choose nest sites to maximize foraging rate? Testing models of nest site selection	2009	Behavioral Ecology and Sociobiology	63	n/a	1353-1362	Japan	nesting / reproduction	Bombus ardens, nest rate of energy intake, nest site, nest searching behavior

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Suzuki Y, Kawaguchi LG, Toquenaga Y	Estimating nest location of bumblebees Bombus ardens from flower quality and distribution	2007	Ecological Research	22	n/a	220-227	Japan	nesting / reproduction	central-place forager, net energy intake rate, colony persistence, reproductive success, nest site
Svensson B, Lagerlof J, Svensson BG	Habitat preferences of nest-seeking bumble bees (Hymenoptera: Apidae) in an agricultural landscape	2000	Agriculture, Ecosystems and Environment	77	n/a	247-255	Sweden	nesting / reproduction	bumble bees, Bombus, nest-seeking, agricultural landscape, habitat selection, Sweden
Svensson BG, Lundberg H	Distribution of bumble bee nests I na subalpine/alpine area in relation to altitude and habitat (Hymenoptera: Apidae)	1977	Zoon	5	n/a	63-72	Sweden	nesting / reproduction	[none]
Svensson BG, Lundberg H	Distribution of bumble bee nests in a subalpine / alpine area in relation to altitude and habitat (Hymenoptera, Apidae)	1977	Zoon	5	1	63-72	Germany	nesting / reproduction	[nest seeking queens, habitat use, altitudinal distribution of species]
Waters J, O'Connor S, Park K, Goulson D	Testing a detection dog to lcoate bumblebee colonies and estimate nest density.	2011	Apidologie	42	2	200-205	UK	nesting / reproduction	nest density, nest odour, Hebrides, Bombus ditinguendus, Bombus muscuourum
Westphal C, Steffan-Dewenter I, Tscharntke T	Mass flowering oilseed rape improves early colony growth but not exual reproduction of bumblebees	2009	Journal of Applied Ecology	46	n/a	187-193	Germany	nesting / reproduction	agroecosystems, Bombus terrestris, bumblebee conservation, ecosystem services, forage plants, landscape-scale study, mass flowering crops, pollination, reproductive success
Whitehorn PR, O'Connor S, Wackers FL, Goulson D	Neonicotinoid pesticide reduces bumble bee colony growth and queen production	2012	Sciencexpress	[online]	n/a	science.1215025	UK	nesting / reproduction	[pesticide exposure, colony growth, reproduction, neonicotinoid imidacloprid]
Whitehorn PR, Tinsley MC, Brown MJF, Darvill B, Goulson D	Impacts of inbreeding on bumblebee colony fitness under field conditions	2009	BMC Evolution Biology	9	n/a	152	UK	nesting / reproduction	[none]
Williams PH	Do the parasite Psithyrus resemble their host bumblebees in colour pattern?	2008	Apidologie	39	n/a	637-649	UK	nesting / reproduction	bumblebee, Bombus, cuckoo bee, colour pattern, mimicry
Wu-Smart J, Spivak M	Effects of neonicitinoid imidacloprid exposure on bumble bee (Hymenoptera: Apidae) queen survival and nest initiation	2018	Environmental Entomology	47	1	55-62	USA	nesting / reproduction	bumble bees, systematic insecticide exposure, nontarget risk
Higginson AD	Conflict over non-partitioned resources may explain between-species differences in declines: the anthropogenic competition hypothesis	2017	Behavoral Ecology and Sociobiology	71	n/a	99	UK	nesting / reproduction, declines and distributions	anthropogenic degredation, competitive exclusion, environmental change, evolutionary stable strategy, pollinator conservation, resource partitioning, seasonal breeding, species declines
Lhomme P, Hines HM	Ecology and evolution of cuckoo bumble bees	2018	Annals of the Entomological Society of America	20	10	1-19	USA	nesting / reproduction, declines and distributions	Psithyrus, social parasitism, inquilinism, Bombus
Fye RE, Medler JT	Spring emergence and floral hosts of Wisconsin bumble bees	1954	Wisconsin Academy of Sciences, Arts and Letters	43	n/a	75-82	USA	nesting / reproduction, flower resource use	[bumble bee queen spring emergence, phenology, flowers, foraging]
Gill RJ, Ramos-Rodriquez O, Raine N	Combined pesticide exposure severly affects individual - and colony-level traits in bees	2012	Nature Letters	n/a	n/a	doi:10.1038/nature11585	UK	nesting / reproduction, flower resource use	[pesticide exposure, neonicotinoid, pyrethroid, colony reproduction]

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Moerman R, Vanderplanck M, Fournier D, Jacquemart A, Michez D	Pollen nutrients better explain bumblebee colony development than pollen diversity	2017	Insect Conservation and Diversity	10	n/a	171-179	Belgium	nesting / reproduction, flower resource use	amino acids, bumblebee, colony, diet, nutrient, sterol
Hass AL, Brachmann L, Batary P, Clough, Behling, Tscharntke	Maize-dominated landscapes reduce bumblebee colony growth through pollen diversity loss	2018	Journal of Applied Ecology	[online]	n/a	1-11	Germany	nesting / reproduction, flower resource use, habitat	bumble bee, colony growth, configurational heterogeneity, crop diversity, landscape heterogeneity, oilseed rape, pollen diversity, pollinator
Herrmann JD, Haddad NM, Levey DJ	Testing the relative importance of local resources and landscape connectivity on Bombus impatiens (Hymenoptera, Apidae)	2017	Apidologie	48	n/a	545-555	USA	nesting / reproduction, flower resource use, habitat	agri-environment, foraging distance, landscape connectivity, habitat fragmentation, floral resources
Amsalem E, Padilla M, Schreiber PM, Altman NS, Hefetz A, Grozinger CM	Do bumble bee, Bombus impatiens, queens signal their reproductive and mating status to their workers?	2017	Journal of Chemical Ecology	43	n/a	563-572	USA	nesting / reproduction, general	reproduction, pheromones, signals, aggression, gene expression
Cnaani J, Schmid-Hempel R, Schmidt JO	Colony development, larval development and worker reproduction in Bombus impatiens Cresson	2002	Insectes Sociaux	49	n/a	164-170	USA	nesting / reproduction, general	Bombus impatiens, larval development, worker reproduction, multiple mating
Couvillon MJ, Dornhaus A	Location, location, location: Larvae position inside the nest is correlated with adult body size in worker bumble-bees (Bombus impatiens)	2009	Proceedings of the Royal Society B	276	1666	2411-2418	USA	nesting / reproduction, general	Bombus impatiens, division of labour, size polygmorphism, alloethism, bumble-bees
Schmid-Hempel R, Schmid-Hempel P	Colony performance and immunocompetence of a social insect, Bombus terrestris, in poor and variable environments	1998	Functional Ecology	12	n/a	22-30	Switzerland	nesting / reproduction, general	colony growth, food availabililty, immunity, reproduction
Bowers MA	Bumble bee colonization, extinction, and reproduction in subalpine meadows in Northeastern Utah	1985	Ecology	66	3	914-927	USA	nesting / reproduction, habitat	Bombus, bumble bees, colonization, community, competition, eusocial insects, extinction, flowers, guilds, insular habitats, life histories, plant-insect interactions
Carvell C, Bourke AFG, Osborne JL, Heard MS	Effects of an agri-environment scheme on bumblebee reproduction at local and landscape scales	2015	Basic and Applied Ecology	16	n/a	519-530	UK	nesting / reproduction, habitat	Bombus, seed mixture, floral density, pollinators, sexual biomass, foraging, landscape scale
Goulson D, Hughes WHO, Derwent LC, Stout JC	Colony growth of the bumblebee, Bombus terrestris, in improved and conventional agricultural and suburban habitats	2002	Oecologia	130	n/a	267-273	UK	nesting / reproduction, habitat	floral resources, farm management, set-aside, foraging, Apidae
Osborne JL, Martin AP, Shortall CR, Todd AD, Goulson D, Knight ME, Hale RJ, Sanderson RA	Quantifying and comparing bumblebee nest densities in gardens and countryside habitats	2008	Journal of Applied Ecology	45	n/a	784-792	UK	nesting / reproduction, habitat	Bombus, environmental stewardship schemes, gardens, nesting habitat, voluntary survey
Samuelson AE, Gill RJ, Brown MJF, Leadbeater E	Lower bumblebee colony reproductive success in agricultural compared to urban environments	2018	Proceedings of the Royal Society B	285	n/a	DOI: 20180807	UK	nesting / reproduction, habitat	urbanization, Bombus terrestris, reproductive success, land use, pollinator ecology, bee
Williams NM, Regetz J, Kremen C	Landscape-scale resources promote colony growth but not reproductive performance of bumble bees	2012	Ecology	93	5	1049-1058	USA	nesting / reproduction, habitat	Apoidea, Bombus, bumble bee, floral resources, landscape structure, pollinator, reproductive success
Vaudo AD, Patch HM, Mortensen DA, Grozinger CM, Tooker JF	Bumble bees exhibit daily behavioral patterns in pollen foraging	2014	Arthropod-Plant Interactions	8	n/a	273-283	USA	pollen use / flower resource use	Bombus impatiens, daily phenology, foraging preferences, native bee conservation, pollination ecology