A Survey of Bumble Bees and Associated Floral Resources at Fort Custer Training Center

Prepared By:
Logan Rowe
Michigan Natural Features Inventory
Michigan State University Extension
P.O. Box 30444
Lansing, MI 48909-7944

Prepared For:
Fort Custer Training Center

12/07/2020

MNFI Report No. 2020-28

Suggested Citation:

Rowe, L. M. 2020. A Survey of Bumble Bees and Associated Floral Resources at Fort Custer Training Center. Michigan Natural Features Inventory, Report No. 2020-28, Lansing, MI.

Cover: Bumble bee foraging from rough blazing star (*Liatris aspera*) at Fort Custer Training Center

Contents

List of Tables

List of Figures

Abstract

Bumble bees (*Bombus* sp.) provide essential pollination services to both natural and managed plant communities. Fort Custer Training Center (FCTC) is located within the current distributions of 11 bumble bee species in Michigan, including at least two at-risk species actively tracked in NatureServe's Biotics network. Despite possible occurrences of at-risk bumble bee species, surveys within suitable habitat at FCTC are lacking. We conducted standardized surveys for bumble bees and documented available flowering resources at 10 locations within FCTC to generate baseline data on bumble bee communities, associated flowering plant species, and the occurrence of at-risk bumble bee species at these locations. Surveys documented three occurrences of the state special concern *B. auricomus* (Black-and-gold bumble bee), representing two distinct Element Occurrences (EOs). In this report, we provide information on the relative abundance and species richness of bumble bees at FCTC, associated floral resources in occupied habitats, and recommendations for management actions that can help support robust plant-pollinator communities and at-risk species.

Introduction

Bumble Bees (*Bombus* sp.) are important pollinators of flowering plants and can play critical roles in the stability of plant-pollinator communities. Historically, Michigan contained approximately 20 unique species of bumble bees, while recent statewide assessments place the current number of species closer to 15 (Rowe *et al*. 2019). Documented declines in bumble bee abundance and species richness relate to increases in pesticides, parasites and pathogens, and habitat loss (NRC 2007). Declines within a landscape could have cascading effects on populations, leading to a decrease in ecosystem services (i.e. pollination) or reduced fitness of flowering plants that rely heavily on bumble bee pollination (Biesmeijer *et al*. 2006). Consequently, bumble bees have received increased conservation attention throughout the Great Lakes Region of the United States.

Once abundant in southwest Michigan, *Bombus affinis* (Rusty patched bumble bee) is now listed as a federally endangered species, and *B. pensylvanicus* (American bumble bee) is currently receiving consideration as a threatened species in the United States. These species have experienced an estimated 100% and 98% decline in their populations in Michigan, respectively (Wood *et al*. 2019). In addition, numerous other bumble bee species are known to be experiencing range contractions (*B. auricomus*, *B. fervidus*, *B. sandersoni*, *B. terricola*). In 2019, Michigan Natural Features Inventory (MNFI) conducted conservation status assessments (s-ranks) for each bumble bee species historically/currently found in Michigan. Each species received a conservation value based on available data regarding species rarity, population trends, and known threats using NatureServe's Element Rank Calculator (Version 2.0, Faber-Langendoen *et al*. 2009). Michigan Natural Features Inventory currently tracks and monitors the statewide occurrences of six species of bumble bees in Michigan (Table 1). When encountered in the field during standardized surveys or when observed incidentally, these species are documented as new or updated Element Occurrences (EOs), providing a baseline for ongoing conservation efforts.

Fort Custer Training Center (FCTC), located in the southwest portion of Michigan's lower Peninsula, is a federally owned military installation operated by the Michigan Army National Guard (MIARNG) that spans 7570 acres in Kalamazoo and Calhoun Counties (Figure 1). Based on its location and the statewide distributions of bumble bees, FCTC is within the current statewide range of 11 bumble bee species, including at least two at-risk species actively tracked my MNFI scientists. While predominately forested, the base has many open locations with ample floral resources that may support bumble bees, both common and rare species. However, surveys to identify these potential habitats, the bumble bee species that occupy them, and the occurrences of at-risk bumble bee species have not been conducted. Therefore, the identification of such habitats, bumble bee communities, and the floral resources commonly used by bumble bee species is needed to develop effective conservation and habitat management plans.

In 2019-2020 MNFI conducted standardize surveys in 10 locations across FCTC property to identify the local bumble bee community, the associations between bumble bees and available floral resources, the relative abundance of flowering plant species, and the presence of at-risk bumble bee species on FCTC property. These surveys provide the first characterization of the bumble bee species of FCTC and enable the identification of habitat management strategies to support robust bumble bee communities and at-risk species at FCTC.

Table 1. At-risk bumble bee species found in Michigan tracked by Michigan Natural Features Inventory Zoologists and recorded within NatureServe's Biotics database. Global ranks, state ranks and state status for each species is provided.

Species	Common Name	Global Rank	State Rank	State Status	Includes FCTC in historic/current distribution (Y/N)
Bombus affinis	Rusty patched bumble bee	G2	SH	proposed Endangered	Y/N
Bombus auricomus	Black-and-gold Bumble Bee	G4G5	S2	Special Concern (SC)	Y/Y
Bombus borealis	Northern Amber Bumble Bee	G4G5	S3	SC	Y/N
Bombus pensylvanicus	American Bumble Bee	G3G4	S1	proposed Threatened	Y/N
Bombus sandersoni	Sanderson's Bumble Bee	G4G5	S2S3	SC	Y/Y
Bombus terricola	Yellow Banded Bumble Bee	G3G4	S2S3	SC	Y/N

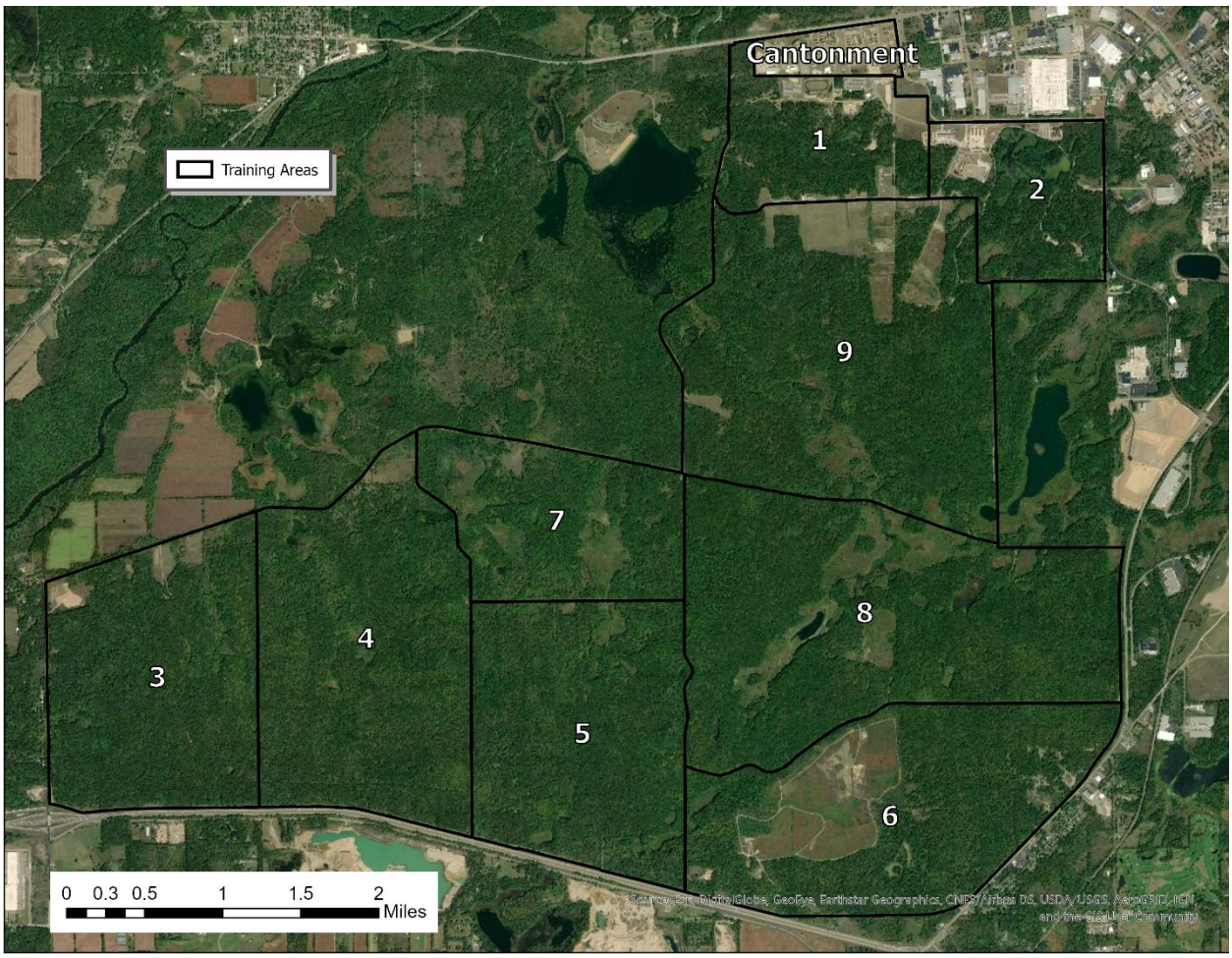


Figure 1. Fort Custer Training Center located in Kalamazoo and Calhoun counties is outlined in black. The base is divided into 9 training areas.

Methods

Bumble bee surveys

During 2019-2020, standardized bumble bee surveys were conducted at FCTC between the months of June and August. Sites were selected by using a combination of available aerial imagery and on-the-ground site visits. First, aerial imagery of the entire base was used to identify herbaceously dominated habitats that had a high likelihood of containing floral resources necessary to support bumble bees. Second, initial site visits were made in June 2019 to assess the quality of the floral habitat at each possible survey location. A total of 10 separate survey locations were selected for bumble bee surveys (Figure 2, Table 2).

Figure 2. Bumble bee survey sites located at Fort Custer Training Center. Complete bumble bee survey areas at each site are highlighted in blue.

Table 2. Location and size of bumble bee survey sites at Fort Custer Training Center.

Site	Acres	Latitude	Longitude
Augusta Rd 1	6.33	42.306515	-85.342505
Augusta Rd East	0.84	42.300798	-85.336094
Mott Rd Fen	2.73	42.298159	-85.324930
Mott Rd North	2.1	42.298298	-85.326342
Mott Rd South	1.64	42.296429	-85.327871
Sand Trail 1	42.7	42.283659	-85.306832
Territorial Rd 1	5.1	42.307376	-85.333267
Territorial Rd 2	5.39	42.300238	-85.365089
Territorial Rd 3	3.14	42.296752	-85.37535
Territorial Rd 4	1.21	42.283528	-85.375531

Bumble bee community surveys were conducted on days that had no rain, temperatures above 15°C (60°F), and when winds were ≤ 25 kph (15 mph). Each site was surveyed by conducting a 30-minute meander walk, focusing survey efforts on patches of available floral resources. Any bumble bee encountered was collected using an aerial net, placed in a plastic vial, and held until the end of the survey. After 30 minutes, the total number of bumble bees collected and bumble bee species richness was recorded. For each bumble bee, we recorded the date, site, species identity, and the plant the bee was collected from. Bumble bees were then released unless a voucher specimen was needed to confirm identification in a lab.

Plant data

We recorded the species richness of flowering plants at each survey location after each bumble bee survey and used a system that ranks flowering plant abundance to characterize the community of available flowering plant species (DAFOR scores; D- Dominate plant species, A- Abundant, F- Frequent, O- Occasional, R- Rare). These standardized scores were converted to a numerical scale for analyses using the following conversions: D=5, A=4, F=3, O=2, R=1. Plant data was recorded for each bumble bee survey site immediately following bumble bee surveys.

Creating Element Occurrences for species tracked by MNFI

Prior to 2019, bumble bee surveys were not conducted at FCTC and therefore no known Element Occurrences previously existed on FCTC property. MNFI currently tracks six species of bumble bees in Michigan (e.g., *Bombus affinis*, B*. auricomus*, *B. borealis*, *B. pensylvanicus*, *B. sandersoni*, *B. terricola*). Any documentation of occurrence for these species gets recorded in NatureServe's Biotics software along with associated habitat information. For at-risk species that were documented between 2019 and 2020, we created Element Occurrences and recorded habitat level information. An overview of these occurrences at FCTC are provided in this report.

Figure 3. David Cuthrell (MNFI Zoologist) conducts survey for bumble bees at Mott Rd South at Fort Custer Training Center.

Results

Bumble bee surveys

From 2019-2020, we conducted a total of 37 bumble bee surveys at 10 locations at FCTC. During these surveys we recorded 698 bumble bee observations (2019: n = 449, 2020: n =249), representing seven distinct species (Table 3). *Bombus impatiens* was the most frequently encountered species (n = 363), followed by *B. bimaculatus* (n = 121) and *B. vagans* (n = 82). The least frequently encountered species was *B. auricomus* (State Special Concern; n = 5). An average of 18.9 bumble bees were observed during 30-minute surveys. In general, we recorded fewer observations per survey in 2020 compared to 2019 (16.9 bees/survey vs. 19.9 bees/survey) (Table 4). Mott Rd Fen had the highest mean abundance of bumble bees (34.5 bees/survey), followed by Augusta Rd 1 (21.25 bees/survey), and Territorial Rd 3 (18.5 bees/survey). Bumble bee activity was greatest during August of both years (2019: 25.3 bumble bees/ survey; 2020: 18.6 bumble bees/ survey). We collected bumble bees from at least 34 different plant species during our surveys in 2019 and 2020 (Table 5, Figure 5). Bumble bees were most frequently collected from spotted knapweed (*Centaure stoebe*; n = 306), followed by wild bergamot (*Monarda fistulosa*; n = 93) and purple loosestrife (*Lythrum salicaria*; n = 78). A complete list of bumble bee species observed, and associated plant species visited at each site is provided in the Appendix (A1).

Table 3. The total number of bumble bees from each species collected at Fort Custer Training Center in 2019 and 2020.

Year	Species	Number of bumble bees observed
2019		
	Bombus auricomus	4
	Bombus bimaculatus	82
	Bombus citrinus	11
	Bombus fervidus	8
	Bombus griseocollis	68
	Bombus impatiens	242
	Bombus vagans	34
2020		
	Bombus auricomus	1
	Bombus bimaculatus	39
	Bombus citrinus	13
	Bombus fervidus	16
	Bombus griseocollis	11
	Bombus impatiens	121
	Bombus vagans	48
Grand Total		**698**

Table 4. The number of surveys, number of bumble bees observed, and mean number of bumble bees per survey at each survey site at Fort Custer Training Center.

Year	Site	Number of times surveyed	Number of bumble bees observed	Bumble bees per 30-minute survey
2019				
	Augusta Rd 1	2	61	30.5
	Augusta Rd East	2	39	19.5
	Mott Rd Fen	1	29	29.0
	Mott Rd North	3	40	13.3
	Mott Rd South	3	56	18.7
	Roadside	NA	6	NA
	Sand Trail 1	3	68	22.7
	Territorial Rd 1	3	58	19.3
	Territorial Rd 2	2	40	20.0
	Territorial Rd 3	2	20	10.0
	Territorial Rd 4	2	32	16.0
	2019 Total	**23**	**449**	**19.9**
2020				
	Augusta Rd 1	2	24	12.0
	Augusta Rd East	1	3	3.0
	Mott Rd Fen	2	80	40.0
	Mott Rd South	1	18	18.0
	Territorial Rd 1	2	14	7.0
	Territorial Rd 2	2	25	12.5
	Territorial Rd 3	2	31	15.5
	Territorial Rd 4	2	54	27.0
	2020 Total	**14**	**249**	**16.9**

Figure 4. Survey area at Territorial Rd 4 with a mix of floral species. Insert: *Bombus bimaculatus* foraging on *Monarda fistulosa*.

Table 5. The relative abundance of each bumble bee species collected from associated floral species at Fort Custer Training Center in 2019 and 2020.

Bumble Bee Species	*Asclepias tuberosa*	*Campanula americana*	*Centaurea stoebe micranthos*	*Chamaecrista fasciculata*	*Cirsium vulgare*	*Coreopsis lanceolata*	*Daucus carota*	*Desmodium sp.*	*Echinacea purpurea*	*Eupatorium perfoliatum*	*Eutrochium purpureum*	*flying*	*Helianthus divaricatus*	*Helianthus occidentalis*	*Hypericum perforatum*	*Leucanthemum vulgare*	*Lythrum salicaria*	*Melilotus albus*	*Monarda fistulosa*	*Oxalis stricta*	*Penstemon digitalis*	*Plantago lanceolata*	*Pycnanthemum virginianum*	*Ratibida pinnata*	*Rubus allegheniensis*	*Silphium integrifolium*	*Solanum carolinense*	*Solidago juncea*	*Solidago nemoralis*	*Solidago sp.*	*Trifolium aureum*	*Trifolium pratense*	*Trifolium repens*	*Vernonia fasciculata*	*Vicia villosa*	**Grand Total**
Bombus auricomus	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	5
Bombus bimaculatus	-	-	19	-	-	-	-	-	-	-	-	1	-	-	-	-	3	-	71	-	6	-	-	-	1	-	-	-	-	-	1	-	15	-	4	121
Bombus citrinus	-	-	6	-	8	1	-	-	1	-	2	-	-	-	-	1	-	-	-	-	-	-	-	1	1	-	-	-	-	-	1	1	1	-	-	24
Bombus fervidus	-	-	2	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	10	-	1	9	24
Bombus griseocollis	-	-	37	-	1	-	3	-	-	-	7	-	-	-	1	-	7	-	7	-	-	-	-	4	1	2	-	-	-	-	2	6	-	1	-	79
Bombus impatiens	6	1	216	3	-	4	2	1	-	1	10	2	1	1	1	-	40	3	8	1	2	2	2	8	5	-	5	2	1	8	4	8	12	-	3	363
Bombus vagans	-	-	25	-	3	1	-	-	-	1	7	-	-	-	-	-	27	-	7	-	4	-	-	-	1	-	-	-	-	-	-	4	-	-	2	82
Grand Total	6	1	306	3	12	6	5	1	1	2	26	4	1	1	2	1	78	3	93	1	12	2	2	13	9	2	6	2	1	8	8	32	28	2	18	**698**

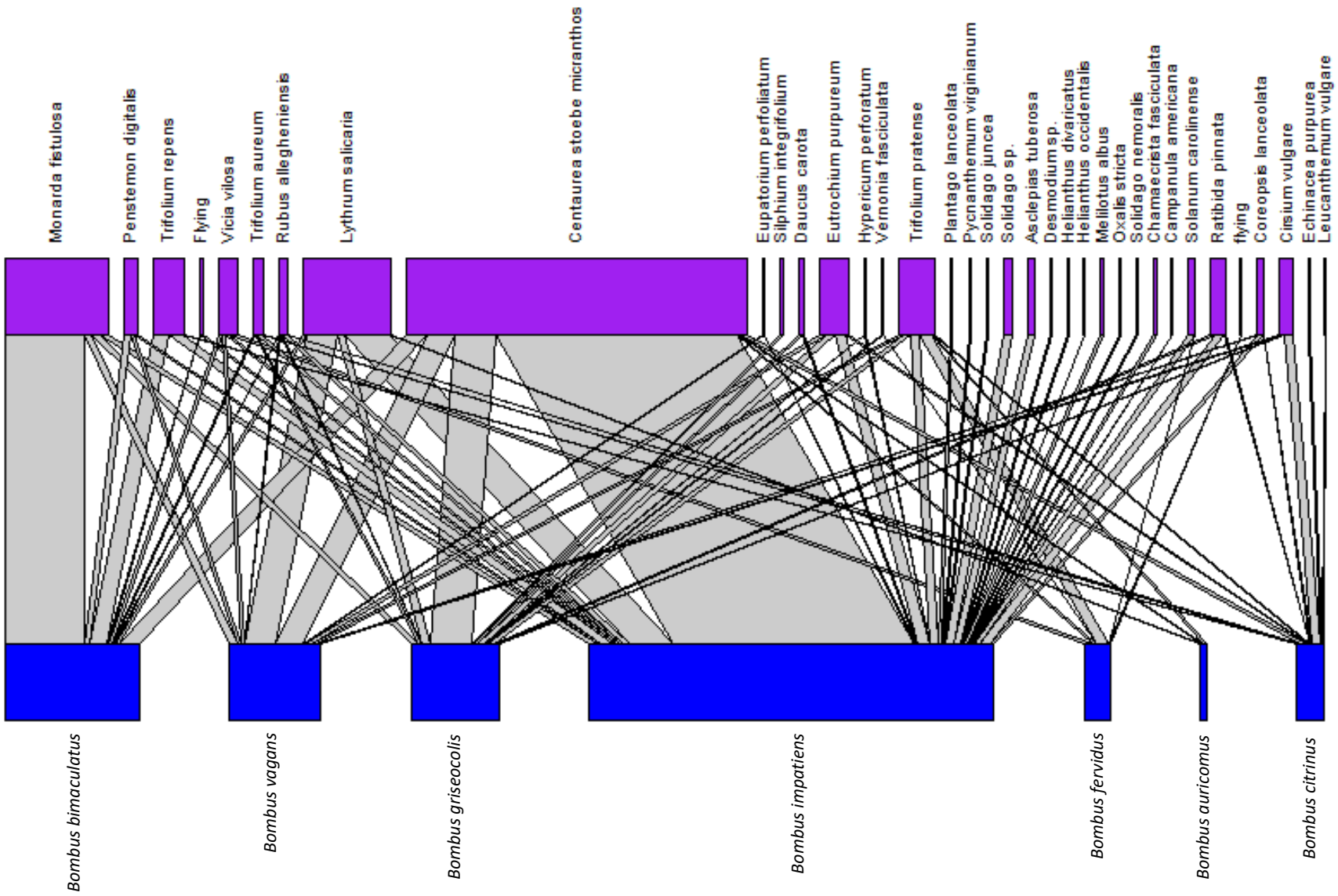


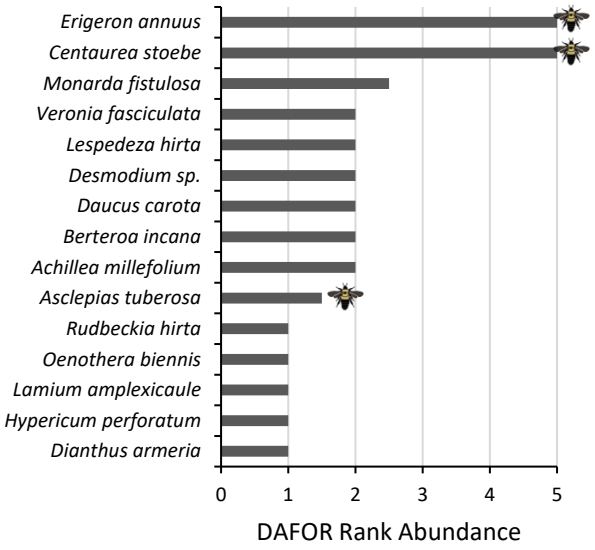
Figure 5. Visualization of the bumble bee - plant visitation network at Fort Custer Training Center. Each bar signifies the use of a floral resource by a species of bumble bee. The width of bars represents the number of interactions or the strength of the relationship.

Available flowering plants

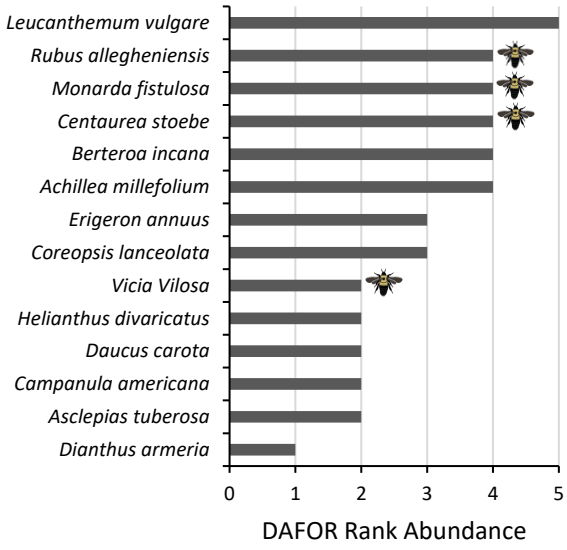
We documented a total 50 flowering plant species within the survey habitats (2019: 38 species; 2020: 32 species). Spotted knapweed (*Centaurea stoebe*) was recorded as a dominate plant species at six survey sites (Augusta Rd 1, August Rd 2, Mott Rd South, Sand Trail 1, Territorial Rd 1, Territorial Rd 3). Other flowering species that were ranked as "dominate" at one or more sites included Fleabane daisy (*Erigeron annuus*; Augusta Rd 1, Territorial Rd 1, Territorial Rd 3), Hoary alyssum (*Berteroa incana*; Mott Rd South), Purple Loosetrife (*Lythrum salicaria*; Mott Rd Fen), Wild bergamot (*Monarda fistulosa*; Territorial Rd 1, Territorial Rd 4), Oxeye daisy (*Leucanthemum vulgare*; Augusta Rd East) Clovers (*Trifolium* sp.; Sand Trail 1, Territorial Rd 2). In general, each site had a unique floral community with a mix of species suitable and unsuitable for bumble bees (Figure 6). Consequently, numerous plant species that bloomed in relatively high abundance at one or more sites had no association with bumble bee visitations (Figure 7A-J).

Figure 6. Flowering plant communities at Augusta Rd East (top) and Augusta Rd 1 (bottom) during surveys in 2019 at Fort Custer Training Center.

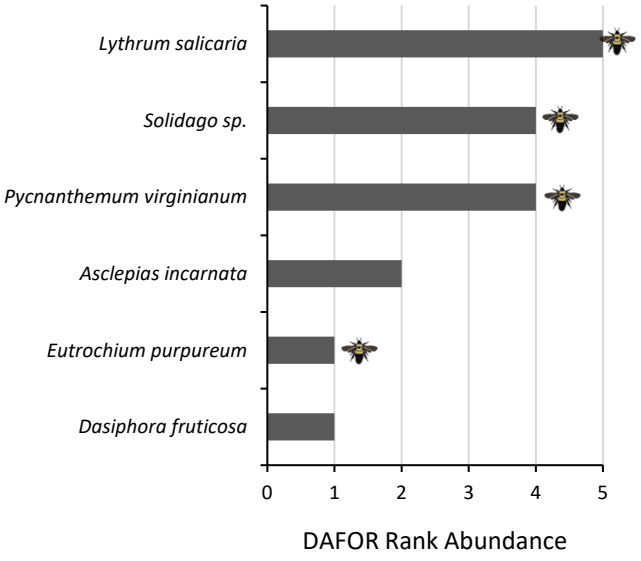
7A) Augusta Rd 1



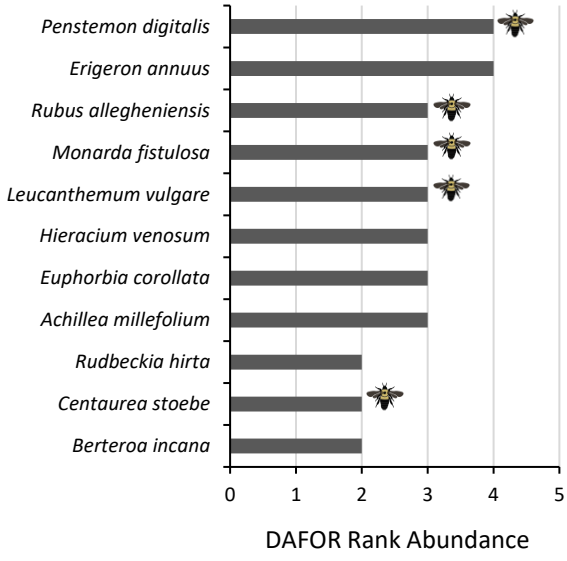
7B) Augusta Rd East



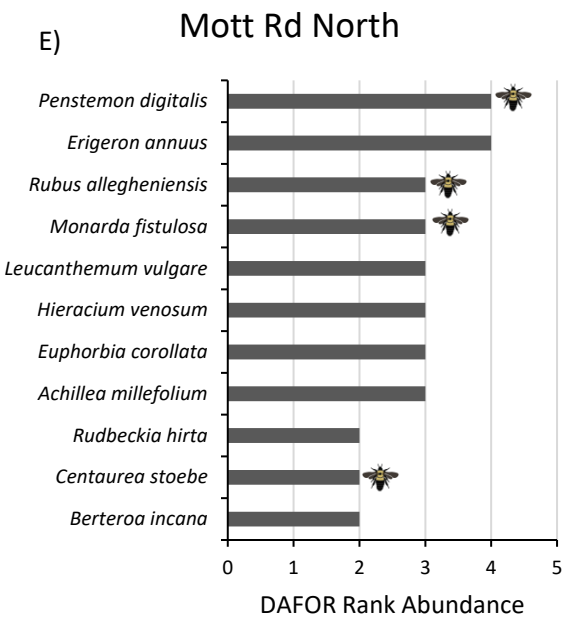
7C) Mott Rd Fen



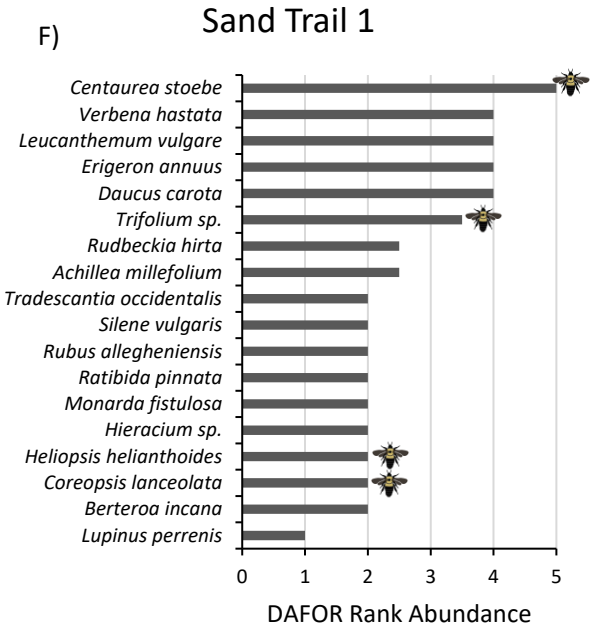
7D) Mott Rd South



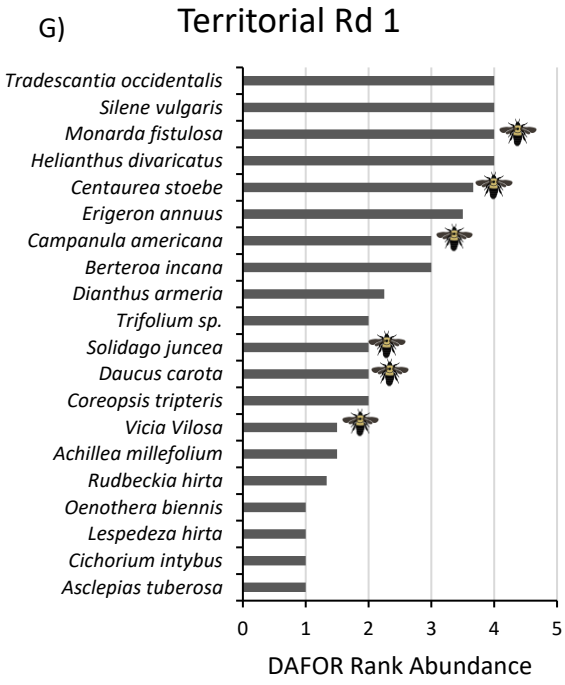
E)


Mott Rd North
Penstemon digitalis
Erigeron annuus
Rubus allegheniensis
Monarda fistulosa
Leucanthemum vulgare
Hieracium venosum
Euphorbia corollata
Achillea millefolium
Rudbeckia hirta
Centaurea stoebe
Berteroa incana
0 1 2 3 4 5
DAFOR Rank Abundance

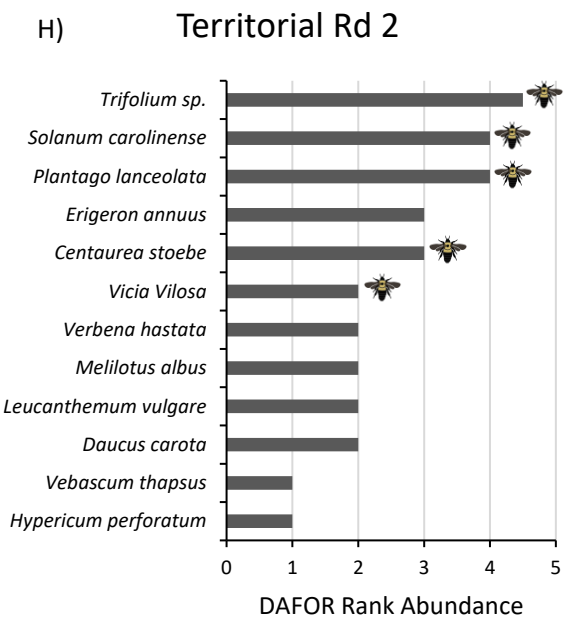
F)


Sand Trail 1
Centaurea stoebe
Verbena hastata
Leucanthemum vulgare
Erigeron annuus
Daucus carota
Trifolium sp.
Rudbeckia hirta
Achillea millefolium
Tradescantia occidentalis
Silene vulgaris
Rubus allegheniensis
Ratibida pinnata
Monarda fistulosa
Hieracium sp.
Heliopsis helianthoides
Coreopsis lanceolata
Berteroa incana
Lupinus perrenis
0 1 2 3 4 5
DAFOR Rank Abundance

G)


Territorial Rd 1
Tradescantia occidentalis
Silene vulgaris
Monarda fistulosa
Helianthus divaricatus
Centaurea stoebe
Erigeron annuus
Campanula americana
Berteroa incana
Dianthus armeria
Trifolium sp.
Solidago juncea
Daucus carota
Coreopsis tripteris
Vicia Vilosa
Achillea millefolium
Rudbeckia hirta
Oenothera biennis
Lespedeza hirta
Cichorium intybus
Asclepias tuberosa
0 1 2 3 4 5
DAFOR Rank Abundance

H)


Territorial Rd 2
Trifolium sp.
Solanum carolinense
Plantago lanceolata
Erigeron annuus
Centaurea stoebe
Vicia Vilosa
Verbena hastata
Melilotus albus
Leucanthemum vulgare
Daucus carota
Vebascum thapsus
Hypericum perforatum
0 1 2 3 4 5
DAFOR Rank Abundance

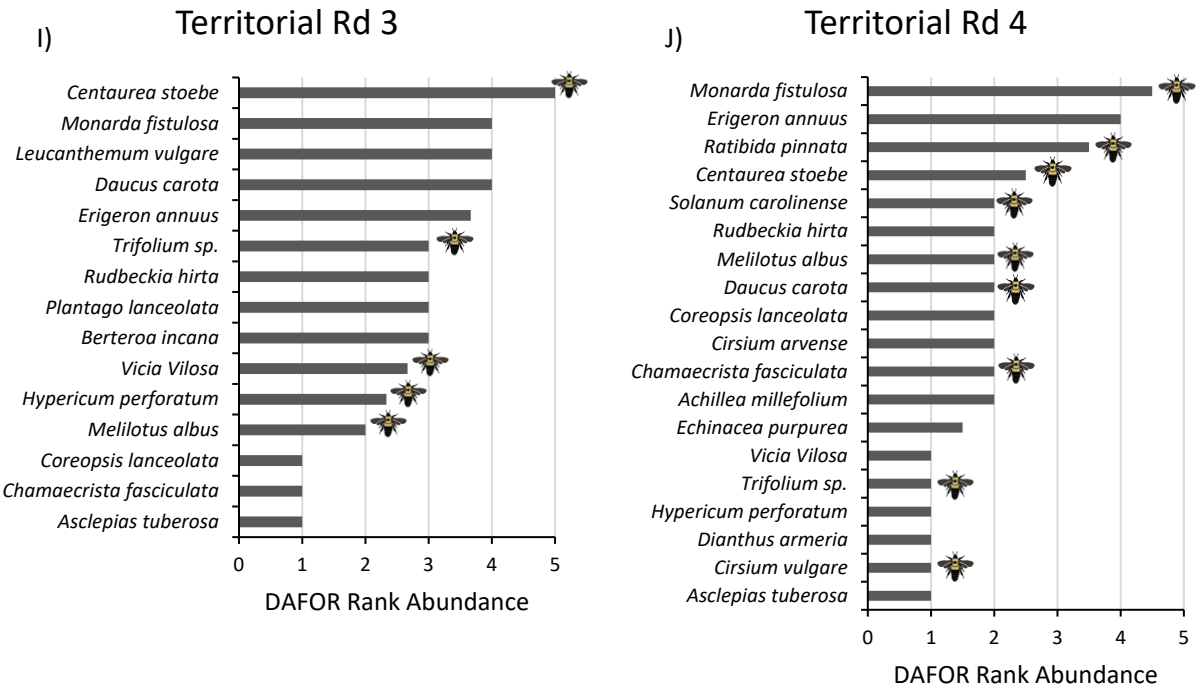


Figure 7. Mean DAFOR Rank Abundance scores (1-5) for each blooming plant species at bumble bee survey sites 7A-7J during 2019 and 2020. Species with a represent species in which bumble bees were observed visiting.

New Element Occurrences for at-risk bumble bee species

During standardized surveys, we documented three locations at FCTC with extant populations of *B. auricomus* (Mott Rd Fen: 42.298159,-85.324930; Territorial Rd 2: 42.300238, -85.365089; Territorial Rd 3: 42.296752, -85.375347). Due to their proximity to each other, Territorial Rd 2 and Territorial Rd 3 are represented as a single Element Occurrence.

Site: Mott Rd. Fen (42.298159,-85.324930)
Species: *Bombus auricomus*
Rank: G4G5, S2, State Species Concern
EO ID: 23693

The area surveyed in Mott Rd Fen encompasses approximately 2.73 acres in the southern section of the fen on the north side of Mott Rd in compartment 7 (Figure 8). The survey area was dominated by purple loosestrife (*Lythrum salicaria*) and mountain mint (*Pycnanthemum virginiaum*), but also contained the following flowering species during bumble bee surveys: swamp milkweed (*Asclepias incarnata*), joe-pye weed (*Eutrochium purpureum*), goldenrods (*Solidago* sp.) and shrubby cinquefoil (*Dasiphora fruticosa*). The proximity of this site adjacent to multiple woodlots suggest at *B. auricomus* may be nesting nearby. Bumble bee surveys were conducted at this site in August 2019, and both July and August 2020, for a total of 1.5 hours. A single *B. auricomus* was observed during the survey in August 2019. In addition to *B. auricomus*, we documented *B. bimaculatus*, *B. citrinus*, *B. griseocollis*, *B. impatiens*, and *B. vagans* at this

site. Purple loosestrife was the primary flowering plant that bumble bees were collected from, however, individuals were also found nectaring on joe-pye weed and goldenrods. This site should be managed to provide floral resources for at-risk bumble bees throughout the duration of the foraging season (June-August). Management that promotes the establishment of native plant species is needed in the fen. Actions could include an herbicide treatment within the heavily dominated purple loosestrife stands, a prescribed burn within the fen, or a release of purple loosestrife beetles *Galerucella pusilla* and *G. calmariensis* to limit the growth and reproduction of the plant.

Figure 8. Location of *B. auricomus* Element Occurrence (EO) in Mott Rd Fen at Fort Custer Training Center.

Site: Territorial Rd 2 (42.300238, -85.365089); Territorial Rd 3 (42.296752, -85.375347)
Species: *Bombus auricomus*
Rank: G4G5, S2, State Species Concern
EO ID: 23638

Territorial Rd 2 is an approximately 5.1-acre managed lot on the south side of Territorial Rd in the northern section of FCTC compartment 3 (Figure 9a). This is primarily a managed lot with low frequency mowing. In the southwest section of this site there is a patch of native and non-native flowering plants. The dominate plant species blooming here include clovers (*Trifolium* sp.) ribwort plantain (*Plantago lanceolate*), fleabane daisy (*Erigeron annuus*), and Carolina horsenettle (*Solanum carolinense*). In addition, oxeye daisy (*Leucanthemum vulgare*), hairy vetch (*Vicia vilosa*), spotted knapweed, white sweetclover (*Melilotus albus*), blue vervain (*Verbena hastata*), queen anne's lace (*Daucus carota*), mullien (*Verbascum thapsus*), and st. john's-wort (*Hypericum perforatum*) were blooming during at least one survey. Surveys were conducted at this site in June and August 2019 and July-August 2020, for a total of two hours. We observed a total of three *B. auricomus* at this site, all foraging from a few species

of clovers, during August 2019. We also documented 12 occurrences of *B. fervidus*, which is a species known to be in decline in Michigan. In addition, we documented *B. bimaculatus*, *B. citrinus*, *B. griseocollis*, *B. impatiens*, and *B. vagans*. Bumble bees at this site relied heavily on clovers during bloom. However, when clovers were not in bloom, bumble bee occurrence numbers drop considerably. Since at-risk bumble bee species utilize this site for floral resources, it is recommended that further incorporation of native floral cover be established on the landscape to provide season long resource availability. With sandy soils, this site would benefit from a dry-sand native plant mix to support bumble bees and other pollinators. A combination of light discing and inter-seeding with a native seed mix could help increase the abundance of native forbs. If pursued, this method should be implemented in strips, leaving some area to remain as clover forage.

Territorial Rd 3 is an approximately 5.4-acre manage lot on the south side of Territorial Rd in the northwest section of FCTC compartment 3 (Figure 9b). This is primarily a managed lot with low frequency mowing. Throughout the site is a mix of native and non-native flowering plants. We documented at least 15 different flowering plant species at this site. However, the site is dominated by spotted knapweed. It also contains high abundances of queen anne's lace (*Daucus carota*), oxeye daisy (*Leucanthemum vulgare*), and wild bergamot (*Monarda fistulosa*). The remaining flowering species include butterfly milkweed (*Asclepias tuberosa*) hoary alyssum (*Berteroa incana*), partridge pea (*Chamaecrista fasciculata*), lance-leaved coreopsis (*Coreopsis lanceolata*), fleabane daisey (*Erigeron annuus*), st. john's wort (*Hypericum perforatum*), white sweetclover (*Melilotus albus*), ribwort plantain (P*lantago lanceolata*), black-eyed susan (*Rudbeckia hirta*), and hairy vetch (*Vicia vilosa*). Surveys were conducted at this site June-July 2019 and July-August 2020, for a total of two hours. We observed a single *B. auricomus* in July 2020 foraging on spotted knapweed. In addition, we documented *B. bimaculatus*, *B. fervidus*, *B. griseocollis*, *B. impatiens*, and *B. vagans*. Spotted knapweed was the primary foraging resources used by bumble bees at this site, followed by clovers and hairy vetch. Since this site contains a relatively high abundance of native plant species, management actions that can support reproduction and establishment of these species is needed. A prescribed burn could reduce the abundance of spotted knapweed while supporting native alternatives (Emory and Gross, 2005). However, to be most effective, these fires should happen annually or every other year.

It is possible that the occurrences of *B. auricomus* at Territorial Rd 2 and Territorial Rd 3 represent individuals from the same or similar colonies. Therefore, additional flowering habitat that helps connect these two sites may be beneficial for supporting foraging bumble bees and connecting otherwise distinct pockets of floral resources. This can be achieved by reducing management along the roadsides or thinning the canopy along the south side of Territorial Rd between the two sites. A series of burns that promote the abundance of floral resources between Territorial Rd 2 and Territorial Rd 3 could be help connect these sites and maintain adequate resource abundance. Having multiple flowering patches within the foraging distance of *B. auricomus* at FCTC can help ensure populations persist if resources become limited.

Figure 9. Location of *B. auricomus* Element Occurrence at Territorial Rd 2(a) and Territorial Rd 3 (b) at Fort Custer Training Center.

Discussion

In this project, we identified locations within Fort Custer Training Center that can provide bumble bees with the foraging resources necessary for colony growth and survival. The restoration and conservation of these landscapes is crucial to supporting robust bumble bee communities and at-risk species. We identified three locations on FCTC property that currently support populations of the at-risk species *B. auricomus*, which has experienced an estimated 65% range contraction in Michigan since the late 1800s (Wood et al. 2019). While some native flowering species are present at Mott Rd Fen, the flowering plant community here is currently dominated by purple loosetrife. Like other invasive species, purple loosestrife can outcompete native plants for resources, resulting in vast monocultures of this species throughout a landscape (Fiedler *et al*. 2012). Although bumble bees will actively forage from purple loosestrife, their diets can become increasingly limited, often resulting in poor overall nutrition and limited access to foraging resources when purple loosestrife is not in bloom (Brown *et al*. 2002). The other two locations with *B. auricomus* face similar pressures, albeit from different plant species. Territorial Rd 2 is dominated by a mix of clovers, while Territorial Rd 3 is dominated by spotted knapweed. Managing these sites in a way that helps add additional native flowering species through means of restoration and conservation efforts will ensure a mixed floral diet and promote the availability of season long foraging resources for at-risk bumble bee species.

While each survey site contains a mix of flowering plant species, we demonstrate that bumble bees will generally visit a subset of the available species, and these patterns are not strictly driven by the abundance of flowering resources at a survey site. It is likely that foraging bumble bees are making foraging decisions to maximize nutritional intake in a way that balances resource availability and nutritional quality of the foraging resources (Vaudo *et al*. 2016). Thus, it is important to have a wide diversity of flowering plants for bumble bees to forage from throughout the foraging timeframe. During

our surveys, we focused our searches in herbaceously dominated landscapes. However, bumble bees will also collect pollen/nectar from blooming trees and shrubs, particularly during the early season when many herbaceous plants haven't yet flowered (Mach *et al*. 2018).

Due to the large acreage of natural cover, FCTC can act as a refuge for at-risk bumble bee species in a broader landscape that is otherwise dominated by agricultural and urban systems. The base contains at least two of the known 33 element occurrences of *B. auricomus* in Michigan. Furthermore, the base itself is within the historic statewide distributions of two nearly extirpated species of bumble bees, *B. affinis* and *B. pensylvanicus*, which have experienced an estimated 100% and 98% decline, respectively. Efforts to provide adequate habitat to help promote populations of these species should be implemented at FCTC, such as limiting pesticide/herbicide use, promoting both herbaceously dominated plant communities and flowering trees and shrubs, and ensuring that these spatially separated habitats are close enough that bumble bees can move between them if experiencing localized pressures. For sites at FCTC with occurrences of at-risk bumble bees (*B. auricomus*), there is increased urgency to implement these various habitat management programs.

Ongoing survey work is needed at FCTC to better understand the ways in which bumble bees (particularly at-risk species) interact with their environments, including foraging preferences, nesting locations, and informed population estimates. The areas surveyed in 2019 and 2020 represent a small fraction of the overall area of FCTC and were completed during the time period when bumble bee workers are most active (late June – late August). Future survey work should prioritize different survey locations with abundant floral resources. These efforts should contain both spring and fall surveys when bumble bees may be foraging from plant species not blooming during the survey timeframe in this study. This would allow for a better representation of bumble bee diets at FCTC and help in the identification of additional floral resources used by bumble bees within the base. By identifying additional locations at FCTC with occurrences of at-risk bumble bee species, targeted habitat management plans can be developed to enhance season long foraging resource availability to fit the dietary needs of bumble bees and to increase the connectedness of utilized floral habitats.

Literature Cited

Biesmeijer, J. C., Roberts, S. P., Reemer, M., Ohlemüller, R., Edwards, M., Peeters, T., et. al., (2006). Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science*, *313*(5785), 351-354.

Brown, B. J., Mitchell, R. J., & Graham, S. A. (2002). Competition for pollination between an invasive species (purple loosestrife) and a native congener. *Ecology*, *83*(8), 2328-2336.

Emery, S. M., & Gross, K. L. (2005). Effects of timing of prescribed fire on the demography of an invasive plant, spotted knapweed Centaurea maculosa. *Journal of Applied Ecology*, *42*(1), 60-69.

Faber-Langendoen D, Master L, Nichols J, Snow K, Tomaino A, BittmanR, Hammerson G, Heidel B, Ramsay L, Young B (2009) NatureServe conservation status assessments: methodology for assigning ranks. NatureServe, Arlington, Virginia.

Fiedler, A. K., Landis, D. A., & Arduser, M. (2012). Rapid shift in pollinator communities following invasive species removal. *Restoration Ecology*, *20*(5), 593-602.

Mach, B. M., & Potter, D. A. (2018). Quantifying bee assemblages and attractiveness of flowering woody landscape plants for urban pollinator conservation. *PLoS One*, *13*(12), e0208428.

National Resource Council. (2007). Status of Pollinators in North America. Washington, D.C.: The National Academies Press.

Rowe, L. M., Cuthrell, D. L., Enander, H. D., (2019). Assessing Bumble Bee Diversity, Distribution, and Status for the Michigan Wildlife Action Plan (No. 2019-33). Report.

Wood, T. J., Gibbs, J., Graham, K. K., & Isaacs, R. (2019). Narrow pollen diets are associated with declining Midwestern bumble bee species. *Ecology*, *100*(6), e02697.

Vaudo, A. D., Patch, H. M., Mortensen, D. A., Tooker, J. F., & Grozinger, C. M. (2016). Macronutrient ratios in pollen shape bumble bee (Bombus impatiens) foraging strategies and floral preferences. *Proceedings of the National Academy of Sciences*, *113*(28), E4035-E4042.

Acknowledgements

Funding for this project was provided by Fort Custer Training Center through the Department of Military and Veterans Affairs. Individuals that helped with bumble bee and habitat surveys include Dave Cuthrell and Courtney Ross. Administrative support was provided by Nancy Toben, Ashley Adkins. Access to FCTC was provided by Michele Richards.

Appendix

Table 6. A1. Complete list of bumble bee and foraging plant interactions by survey location in 2019-2020 at Fort Custer Training Center

Site	Plant Species	*Bombus auricomus*	*Bombus bimaculatus*	*Bombus citrinus*	*Bombus fervidus*	*Bombus griseocollis*	*Bombus impatiens*	*Bombus vagans*
Augusta Rd 1	*Asclepias tuberosa*	0	0	0	0	0	6	0
	Centaurea stoebe micranthos	0	3	0	1	1	52	3
	Chamaecrista fasciculata	0	0	0	0	0	1	0
	Flying	0	1	0	1	0	0	0
	Helianthus occidentalis	0	0	0	0	0	1	0
	Monarda fistulosa	0	12	0	0	2	1	0
Augusta Rd East	*Centaurea stoebe micranthos*	0	1	0	0	4	12	2
	Chamaecrista fasciculata	0	0	0	0	0	1	0
	Coreopsis lanceolata	0	0	1	0	0	3	1
	Monarda fistulosa	0	13	0	0	0	0	1
	Rubus allegheniensis	0	0	0	0	0	0	1
	Vicia vilosa	0	0	0	0	0	1	1
Mott Rd Fen	*Cirsium vulgare*	0	0	0	0	0	0	1
	Eutrochium purpureum	0	0	2	0	6	8	3
	Helianthus divaricatus	0	0	0	0	0	1	0
	Lythrum salicaria	1	3	0	0	7	40	27
	Pycnanthemum virginianum	0	0	0	0	0	2	0
	Solidago sp.	0	0	0	0	0	8	0
Mott Rd North	*Centaurea stoebe micranthos*	0	4	0	0	3	10	3
	Monarda fistulosa	0	5	0	0	1	0	0
	Penstemon digitalis	0	5	0	0	0	1	4
	Rubus allegheniensis	0	1	1	0	0	2	0
Mott Rd South	*Centaurea stoebe micranthos*	0	3	0	0	10	38	8
	Desmodium sp.	0	0	0	0	0	1	0
	Flying	0	0	0	0	0	2	0
	Leucanthemum vulgare	0	0	1	0	0	0	0
	Monarda fistulosa	0	3	0	0	1	0	0
	Penstemon digitalis	0	1	0	0	0	1	0
	Rubus allegheniensis	0	0	0	0	1	3	0
	Trifolium aureum	0	0	1	0	0	0	0
Roadside	*Solidago juncea*	0	0	0	0	0	1	0
	Hypericum perforatum	0	0	0	0	1	0	0

Site	Plant Species	*Bombus auricomus*	*Bombus bimaculatus*	*Bombus citrinus*	*Bombus fervidus*	*Bombus griseocollis*	*Bombus impatiens*	*Bombus vagans*
	Trifolium aureum	0	0	0	0	0	2	0
	Trifolium repens	0	2	0	0	0	0	0
Sand Trail 1	*Centaurea stoebe micranthos*	0	5	0	0	12	36	1
	Coreopsis lanceolata	0	0	0	0	0	1	0
	Silphium integrifolium	0	0	0	0	2	0	0
	Trifolium aureum	0	1	0	0	2	2	0
	Trifolium repens	0	6	1	0	0	0	0
Territorial 1	*Campanula americana*	0	0	0	0	0	1	0
	Centaurea stoebe micranthos	0	1	4	0	4	30	4
	Daucus carota	0	0	0	0	0	1	0
	Monarda fistulosa	0	5	0	0	2	5	4
	Solidago juncea	0	0	0	0	0	1	0
	Solidago nemoralis	0	0	0	0	0	1	0
	Vernonia fasciculata	0	0	0	0	1	0	0
	Vicia vilosa	0	1	0	4	0	2	0
Territorial 2	*Centaurea stoebe micranthos*	0	0	0	1	0	6	0
	Eupatorium perfoliatum	0	0	0	0	0	1	1
	Eutrochium purpureum	0	0	0	0	1	2	4
	Plantago lanceolata	0	0	0	0	0	2	0
	Solanum carolinense	0	0	0	1	0	0	0
	Trifolium pratense	3	0	1	6	6	8	2
	Trifolium repens	0	6	0	0	0	10	0
	Vicia vilosa	0	0	0	4	0	0	0
Territorial 3	*Centaurea stoebe micranthos*	1	2	0	0	2	26	4
	Hypericum perforatum	0	0	0	0	0	1	0
	Melilotus albus	0	0	0	0	0	1	0
	Trifolium pratense	0	0	0	3	0	0	2
	Trifolium repens	0	1	0	0	0	2	0
	Vernonia fasciculata	0	0	0	1	0	0	0
	Vicia vilosa	0	3	0	1	0	0	1
Territorial 4	*Centaurea stoebe micranthos*	0	0	2	0	1	6	0
	Chamaecrista fasciculata	0	0	0	0	0	1	0
	Cirsium vulgare	0	0	8	0	1	0	2
	Daucus carota	0	0	0	0	3	1	0
	Echinacea purpurea	0	0	1	0	0	0	0
	Melilotus albus	0	0	0	0	0	2	0
	Monarda fistulosa	0	33	0	0	1	2	2

Site	Plant Species	*Bombus auricomus*	*Bombus bimaculatus*	*Bombus citrinus*	*Bombus fervidus*	*Bombus griseocollis*	*Bombus impatiens*	*Bombus vagans*
	Oxalis stricta	0	0	0	0	0	1	0
	Ratibida pinnata	0	0	1	0	4	8	0
	Solanum carolinense	0	0	0	0	0	5	0
	Trifolium pratense	0	0	0	1	0	0	0