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# Distribution and conservation status of bumble bees in New York State, USA

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**Abstract.** Bumble bees (*Bombus* spp.) are important pollinators and charismatic ambassadors for conservation, yet some species have declined drastically. Pesticides, habitat loss, and climate change have all been implicated in documented declines. State-level inventories are important for designating Species of Greatest Conservation Need and for state listings as endangered or threatened. In New York, the Empire State Native Pollinator Survey (ESNPS), which ran from 2018–2021, combined field surveys with compilations of museum records and community (citizen) science. We used the resulting data to map the distributions of all of New York's *Bombus* species pre-2000 and from 2000–2021, calculate conservation status ranks (S-ranks), and look for phenological changes. We analyzed over 43,000 records of 18 species and found that the conservation status of 12 species changed compared to their status prior to the ESNPS. Following the ESNPS, 13 species were assessed as Imperiled (S2), Vulnerable (S3), or Possibly Extirpated (SH). The at-risk species included several cuckoo bumble bees plus species with long tongues that nest aboveground and prefer open habitats. Species in the subgenera *Thoracobombus*, *Bombias*, *Bombus*, and *Psithyrus* were assessed as most imperiled. Overall, observation dates were later in the season but varied widely by species; more targeted studies of emergence dates and floral availability are needed to determine whether bumble bee phenology has shifted in the study area. Further inventory and monitoring of select at-risk species will document new occurrences and enable tracking status over time. Retaining New York's bumble bee diversity requires protecting habitat, further reducing pesticide use, and mitigating climate change.

## INTRODUCTION

Over one-third of the food humans consume is dependent on pollinators and three-quarters of crops worldwide show increased fruit set with animal pollination (Klein *et al.*, 2007). In addition, because nearly 90% of all flowering plants require animal pollination, changes in pollinator populations can have major impacts on the ecosystems humans rely on (Ollerton *et al.*, 2011). Among pollinating insects, bees have been shown to be efficient pollinators because they actively collect pollen for their young, making direct contact with flower stigmas, and they visit many flowers

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(Portman *et al.*, 2019; Bernauer *et al.*, 2022; Roquer-Beni *et al.*, 2022). Bumble bees (Hymenoptera: Apidae: *Bombus* Latreille) in particular carry large pollen loads across relatively long distances and are charismatic ambassadors for conservation. Yet some species have experienced drastic declines (Cameron & Sadd, 2020; Grixti *et al.*, 2009). Nearly 30% (13 of the 46) of North American bumble bee species assessed by the International Union for the Conservation of Nature (IUCN) declined in distribution or abundance compared to earlier records (Hatfield *et al.*, 2015). Some species are stable or expanding their ranges (Bartomeus *et al.*, 2013) but rangewide patterns may not accurately predict local ones; for example, some pollinators that are secure range wide may be in decline locally, or vice-versa (Jackson *et al.*, 2022; Klymko *et al.*, 2023).

Bumble bees are negatively affected by climate change (Soroye *et al.*, 2020), introduced parasites and pathogens (Cameron *et al.*, 2011, 2016), pesticide use (Whitehorn *et al.*, 2012; Hatfield & Jepsen, 2021), and habitat degradation and loss (Cameron & Sadd, 2020). According to the IUCN, information needed to assess the conservation status of about 13% (6 of the 46) of North American bumble bee species is lacking (Hatfield *et al.*, 2015). With known declines, it is important to document species occurrences and range extents (Portman & Dolan, 2022). By filling information gaps and meeting local and regional needs for bumble bee status assessments, smaller-scale studies have helped refine our understanding of trends and contributed data to inform state Endangered and Threatened lists and status as Species of Greatest Conservation Need (SGCN). Other northeastern U.S. states such as Vermont (Richardson *et al.*, 2019), Maine (Bickerman-Martens *et al.*, 2017), and Rhode Island (Varkonyi *et al.*, 2025) have conducted statewide bumble bee surveys. These surveys have provided information necessary for SGCN designations (deMaynadier *et al.*, 2024) and state listings.

New York recently completed a multiyear, statewide effort to summarize historical information and obtain new data on the distribution and status of native pollinators, and bumble bees were one of the focal taxa (White *et al.*, 2022). Using this up-to-date dataset, we have created statewide distribution maps, updated conservation status ranks, and examined phenological data. In this paper, we present these findings and provide species-specific profiles in which we discuss life history, habitat, distribution, and trends to help guide conservation and management efforts.

## MATERIAL AND METHODS

DATA: The Empire State Native Pollinator Survey (ESNPS) assessed the current and historical distribution of pollinators in several insect orders (Hymenoptera, Diptera, Coleoptera, and Lepidoptera) with three field sampling strategies and compilation of existing data, resulting in up-to-date information on the occurrence of bumble bees across New York (Schlesinger *et al.*, 2023). Sampling efforts were concentrated on protected lands and balanced across major habitat types – including meadow/grassland, forest, wetland, and roadside – across all Level III ecoregions (Bailey, 1997) in the state (North Atlantic Coast, Northern Appalachian/Acadian, Great Lakes, High Allegheny Plateau, Lower New England/Northern Piedmont, St. Lawrence-Champlain Valley, and Western Allegheny Plateau). Additionally, specific habitats thought to harbor a unique pollinator fauna were targeted to ensure that they were not under-surveyed: alpine meadows, barrens, coastal dunes, peatlands, and late-successional forests. A typical survey included four transects of pan traps and 120 minutes of hand netting by two surveyors on a single day from April–October, 2017–2020 (see White *et al.*, 2022; Schlesinger *et al.*, 2023 for more details on sampling methods).

Additional targeted surveys for at-risk *Bombus* species were conducted in suitable habitat near historical locations for Rusty-patched Bumble Bee (*B. affinis*), Ashton's Cuckoo Bumble Bee (*B. bohemicus* [= *ashtoni*]), Indiscriminate Cuckoo Bumble Bee (*B. insularis*), Appalachian Cuckoo Bumble Bee (*B. flavidus appalachiensis* [= *fernaldae*]),

Yellow-banded Bumble Bee (*B. terricola*), American Bumble Bee (*B. pensylvanicus*), Yellow Bumble Bee (*B. fervidus*), Black and Gold Bumble Bee (*B. auricomus*), and Northern Amber Bumble Bee (*B. borealis*). Taxonomic authorities are listed in Appendix S1. All told, we surveyed 281 extensive, target habitat, and target species sites. Field data were supplemented by incidental and iNaturalist records, partner datasets, and available records in published and unpublished literature (see Table S2 for full list of sources). As the final dataset included this compilation from multiple partners, duplicate records could have been introduced; however, duplication is immaterial for county-level presence/nondetection maps (see Mapping, below). Identification to species was performed by KH and EW for newly collected specimens using Williams *et al.* (2014). Collected specimens have been labeled with unique identifiers and barcodes. So far 3,474 specimens (of 3,485) have been deposited at the New York State Museum (NYSM) Entomology Collection in Albany, New York, and may be referenced for future studies.

*Bombus flavidus* is unique among bumble bees for having a global distribution (Lhomme *et al.*, 2021). While there has been taxonomic uncertainty surrounding *B. flavidus*, Lhomme *et al.* (2021) used genetic analysis, chemical composition, and morphological features to recognize *B. flavidus appalachiensis* as a distinct subspecies restricted to eastern North America (NatureServe, 2025). We refer to the eastern subspecies, *B. f. appalachiensis* as *B. flavidus* throughout this paper when the primary literature does not reflect the subspecies distinction. All *B. flavidus* specimens observed and collected in the state of New York are treated as *B. f. appalachiensis*.

Mapping: We compiled historical (pre-2000) and current (2000–2021) bumble bee records to create species-specific distribution maps. We used the R programming language (R Core Team, 2025) with packages 'RODBC' (Ripley & Lapsley, 2024; to connect to local databases), 'sf' (Pebesma, 2018; to read spatial data), and 'tmap' (Tennekes, 2018; to plot spatial data), all within the integrated development environment Positron (version 2025.07.0-204; https://positron.posit.co/). These distribution maps represent 1) historical county-level records overlain by iNaturalist, partner, and ESNPS specimen records, and 2) historical and recent county-level records.

Conservation ranks: We used NatureServe's conservation status ranking approach (Master *et al.*, 2012; Faber-Langendoen *et al.*, 2012) to update subnational ranks (S-ranks) for all *Bombus* species known for New York State. Prior to the ESNPS, New York S-ranks had been based on museum and other pre-2010 data compiled by Richardson (unpubl. data) and Yanega (unpubl. data). S-ranks reflect a species' degree of imperilment in a state or province and are based on rarity, threats, and trends. We calculated Range Extent, Area of Occupancy, and Number of Occurrences based on "post-1999" (2000–2021) records to represent rarity, assigned a High threat level to most species (or for species facing fewer threats an Intrinsic Vulnerability score of Moderately Vulnerable), and calculated long-term trend based on county occupancy in 2000–2021 and pre–2000 data as detailed in Schlesinger *et al.* (2023). For consistency among species, we used the NatureServe rank "calculator" (NatureServe, 2020) to generate S-ranks, which ranged from SH, S1 to S5 (Schlesinger *et al.*, 2023). Calculated conservation status ranks were reviewed by the authors to fairly reflect each species' imperilment or security.

Phenology: To examine changes in species phenology over time, we calculated the number of days since January 1 for each record with an exact date after removing duplicate records. Some older records with limited detail, containing only the month and year, were not included. After omitting records without exact dates, we used approximately 15,000 unique date-location records for phenological analysis. We generated boxplots to display the distribution of dates visually for each of the nine species with 100 or more records in each time period, and for all *Bombus* pooled, using R package ggplot2 (Wickham, 2016). We also conducted Kolmogorov–Smirnov tests using R (R Core Team, 2023) in RStudio (Posit Team, 2023) to test the hypothesis that

pre–2000 and 2000–2021 observations came from the same distribution of dates using $\alpha = 0.05$.

## RESULTS

Over 43,000 bumble bee records were collected, reviewed, and cataloged in the ESNPS database (Table S2). These included an unknown number of duplicates because data were compiled from multiple sources that overlapped in records (White *et al.*, 2022). In total, 43,084 records had date and county-level information and were included in statewide mapping and conservation rank updates. In all, we documented 18 species of *Bombus* as currently or formerly occurring in New York State (Table 1).

MAPPING: Statewide distribution maps are provided in Appendix S1.

CONSERVATION RANKS: The recent survey efforts contributed to a better understanding of the conservation status of New York's bumble bee species; ranks of approximately 70% (12 of 18) of species changed when comparing the pre-ESNPS conservation status and post-ESNPS conservation status. Four species (*B. citrinus*, *B. perplexus*, *B. bimaculatus*, and *B. griseocollis*) were assessed as being of greater concern than prior to the ESNPS, and eight species were assessed as being of lower concern; however, over half of these are still considered at-risk species with S-ranks of S2, S2S3, and S3.

Three species were not re-detected in New York during the survey effort and are considered Possibly Extirpated (SH): *B. affinis*, *B. bohemicus*, and *B. insularis*. The remaining 15 species were detected during the 2017–2021 survey period. One highlight from the 4-year survey effort was the rediscovery of *B. f. appalachiensis*, changing the status of this bee from Possibly Extirpated (SH) to Imperiled (S2). Nearly 75% of the species (13 of 18) were assessed as Imperiled (S2), Vulnerable (S3), or Possibly Extirpated (SH). The S2 and S2S3 species have long tongues, generally nest at the ground surface, and prefer more open habitats (*B. auricomus* and *B. pensylvanicus*), or are cuckoo bumble bees (*B. f. appalachiensis* and *B. citrinus*) (Table S1, Appendix S1).

*Bombus* (*Psithyrus*) *suckleyi* Greene was previously thought to occur in New York; however, in 2023, the United States Fish and Wildlife Service confirmed that the two historic records, from Tompkins and Ulster Counties, thought to be *B. suckleyi* are instead *B. bohemicus* (J. Evertt, pers. comm.). *Bombus* (*Psithyrus*) *variabilis* (Cresson) was reported from New York based on two historical records from the early 1900s from Ulster and Essex Counties in the USDA-ARS/Harvard collection. An attempt was made to locate these specimens, and they could not be relocated in the collection potentially due to the material being re-identified, not databased, or undetermined (C. Maier, pers. comm., K. Wright, pers. comm.). We were unable to confirm the presence of *B. variabilis* at this time, and it is not included in summary tables and species profiles.

Overall, 72% (13 of 18) of New York's bumble bees are experiencing some level of risk (SH to S3) and the remaining 28% (5 of 18) are considered secure (S4 or S5). Approximately 17% (3 of 18) of New York's bumble bees are Potentially Extirpated (SH) from the state and 22% (4 of 18) are considered Imperiled (S2) or Imperiled-Vulnerable (S2S3).

PHENOLOGY: Apparent changes in phenology, as measured crudely by dates of observations, varied by species. With all *Bombus* pooled, mean observation dates were 10 days later in the recent time period (2000–2021) than historically (pre–2000), and the distributions of observation dates differed significantly (Table 2; Figure 1). This overall pattern was driven by *B. impatiens*, *B. citrinus*, and *B. terricola*, all of which had mean observation dates 9 or more days later in the recent time period (Table 2, Figure 2). Conversely, just two species (*B. perplexus* and *B. bimaculatus*) had mean observation dates earlier in the recent time period, but only the distributions of *B. perplexus* dates were significantly different.

**Table 1.** IUCN Red List and conservation ranks of *Bombus* species recorded in New York State. Species are indicated as having no change in status (nc) or being of greater conservation concern (gc) or lower conservation concern (lc) than prior to the Empire State Native Pollinator Survey (ESNPS). Common names follow NatureServe Explorer (2025). Abbreviations: G-rank = Global conservation rank; Pre-ESNPS/Post-ESNPS = State rank before and after ESNPS. *Rare and imperiled species; †Additional records since the ESNPS; these records are not reflected in the table and may warrant reassessment. Taxonomic authorities are in Appendix S1.

| Species | Common name | IUCN category | IUCN Population Trend | G-rank | Pre-ESNPS | Post-ESNPS |
|---|---|---|---|---|---|---|
| *B.* (*Bombias*) *auricomus*[lc] | Black-and-gold bumble bee | LC | Stable | G5 | S1 | S2*† |
| *B.* (*Bombus*) *affinis*[nc] | Rusty-patched bumble bee | CR | Decreasing | G2 | SH | SH* |
| *B.* (*Bombus*) *terricola*[lc] | Yellow-banded bumble bee | VU | Decreasing | G3G4 | S1 | S3 |
| *B.* (*Cullumanobombus*) *griseocollis*[gc] | Brown-belted bumble bee | LC | Stable | G5 | S5 | S4S5 |
| *B.* (*Cullumanobombus*) *rufocinctus*[nc] | Red-belted bumble bee | LC | Stable | G5 | S3 | S3 |
| *B.* (*Psithyrus*) *bohemicus* (=*ashtoni*)[nc] | Ashton cuckoo bumble bee | DD | Decreasing | G3G5 | SH | SH* |
| *B.* (*Psithyrus*) *citrinus*[gc] | Lemon cuckoo bumble bee | LC | Stable | G4 | S5 | S2S3* |
| *B.* (*Psithyrus*) *flavidus appalachiensis*[lc] | Appalachian cuckoo bumble bee | DD | Stable | G5 | SH | S2*† |
| *B.* (*Psithyrus*) *insularis*[nc] | Indiscriminate cuckoo bumble bee | LC | Stable | G3 | SH | SH* |
| *B.* (*Pyrobombus*) *bimaculatus*[gc] | Two-spotted bumble bee | LC | Stable | G5 | S5 | S4S5 |
| *B.* (*Pyrobombus*) *impatiens*[nc] | Common eastern bumble bee | LC | Stable | G5 | S5 | S5 |
| *B.* (*Pyrobombus*) *perplexus*[gc] | Confusing bumble bee | LC | Stable | G5 | S4 | S3 |
| *B.* (*Pyrobombus*) *sandersoni*[nc] | Sanderson's bumble bee | LC | Stable | G5 | S3 | S3 |
| *B.* (*Pyrobombus*) *ternarius*[lc] | Tri-colored bumble bee | LC | Stable | G5 | S3 | S4S5 |
| *B.* (*Pyrobombus*) *vagans*[lc] | Half-black bumble bee | LC | Stable | G4 | S4 | S5 |
| *B.* (*Subterraneobombus*) *borealis*[lc] | Northern amber bumble bee | LC | Stable | G4G5 | S1 | S3 |
| *B.* (*Thoracobombus*) *fervidus*[lc] | Yellow bumble bee | VU | Decreasing | G3 | S1 | S3 |
| *B.* (*Thoracobombus*) *pensylvanicus*[lc] | American bumble bee | VU | Decreasing | G3G4 | S1 | S2* |

**Table 2.** Numbers of New York *Bombus* records with exact dates pre-2000 and from 2000–2021, mean number of days different between the two periods (negative values are earlier pre-2000 than post-1999), and results of two-sample Kolmogorov-Smirnov tests for difference in the distribution of dates. The test statistic, *D*, is annotated by an asterisk when differences were significant (all had $P < 0.001$).

| Species | Total Records | Pre-2000 | Post-1999 | Days different | *D* |
|---|---|---|---|---|---|
| *B. bimaculatus* | 1,146 | 172 | 974 | -2.1 | 0.076 |
| *B. citrinus* | 385 | 132 | 253 | 13.9 | 0.236* |
| *B. fervidus* | 951 | 337 | 614 | 4.7 | 0.137* |
| *B. griseocollis* | 1,951 | 123 | 1,828 | 0.4 | 0.049 |
| *B. impatiens* | 5,657 | 623 | 5,034 | 17.4 | 0.153* |
| *B. perplexus* | 691 | 287 | 404 | -1.5 | 0.161* |
| *B. ternarius* | 601 | 140 | 461 | 3.9 | 0.093 |
| *B. terricola* | 669 | 484 | 185 | 9.2 | 0.199* |
| *B. vagans* | 732 | 314 | 418 | 1.6 | 0.068 |
| All species | 13,956 | 3,323 | 10,633 | 10.0 | 0.088* |

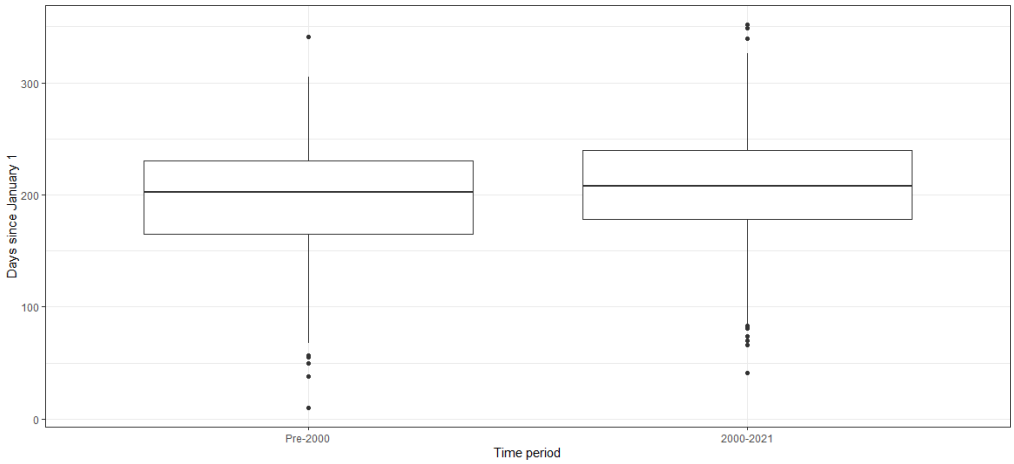


**Figure 1.** Dates of observations of all *Bombus* species pre–2000 ($n$ = 3,323) and from 2000–2021 ($n$ = 10,633) in New York State.

## DISCUSSION

New York's bumble bees have undergone dramatic changes in the last several decades. Over 70% of species (13 of 18) are at some risk of extirpation from the state or are already presumed extirpated. Most species' calculated status was less imperiled than in a previous assessment, but several species' status was more imperiled. Although identifying individual stressors or drivers of change is beyond the scope of this paper, morphology, life history, and nesting habits (Table S1) may explain some differences in risk and vulnerability among species.

The subgenus *Pyrobombus* appears to be of lowest concern when compared to other subgenera, with all members in this group having subnational conservation

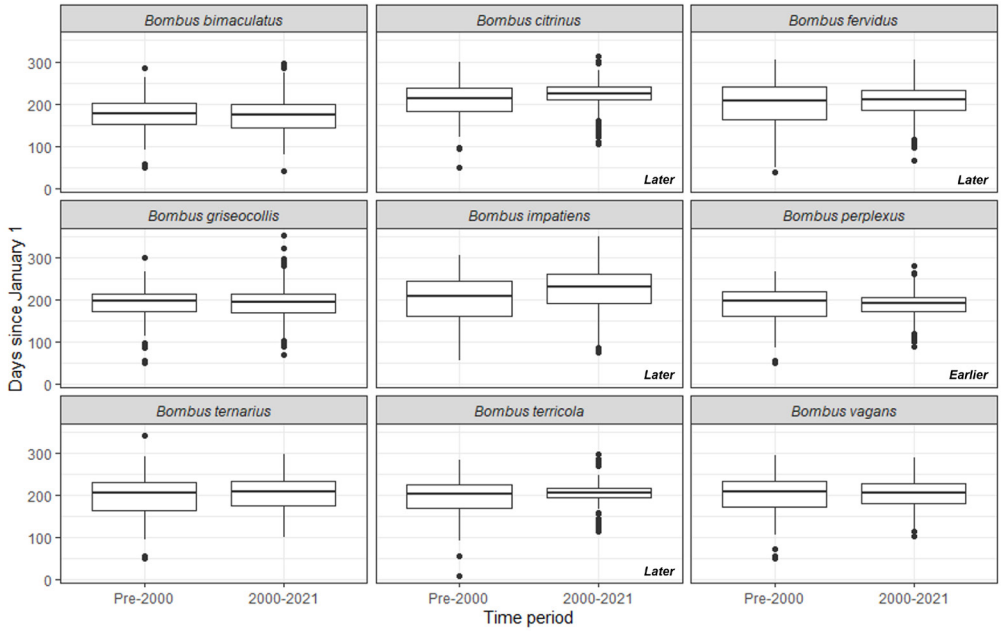


**Figure 2.** Dates of observations of the nine most common *Bombus* species pre–2000 and from 2000–2021 in New York. Text in the lower right corner of plots indicates significantly earlier or later observation dates (Kolmogorov-Smirnov test, $P < 0.05$).

ranks of Vulnerable (S3), Apparently Secure (S4), or Secure (S5). *Bombus bimaculatus* and *B. impatiens* have expanded their distribution relative to other species; elsewhere they have been documented to be stable (Cameron *et al.*, 2011; Wood *et al.*, 2019) or increasing (Jacobson *et al.*, 2018; Jackson *et al.*, 2022). *Bombus ternarius* populations appear to be increasing in the northeast, while *B. perplexus* and *B. sandersoni* are consistently detected in low numbers (Jacobson *et al.*, 2018). Species in the subgenus *Pyrobombus* share morphological and life history traits. All members in New York have a medium tongue length and nest belowground (Williams *et al.*, 2014). Nesting belowground may buffer colonies from environmental threats such as pesticide exposure and climate change.

*Bombus impatiens* and *B. vagans* were our two most abundant species in the ESNPS collection. These two species are considered important pollinators as shown by their broad floral breadth (Jacobson *et al.*, 2018). The observed abundance of *B. impatiens* may be attributed in part to its tolerance to pesticide exposure, broad diet, early seasonal activity, and longer activity period, allowing it to adapt to changes in the landscape and floral phenologies (Colla & Packer, 2008; Cameron *et al.*, 2016; Jacobson *et al.*, 2018). Further, this species is more common in agricultural areas (Hemberger *et al.*, 2021), demonstrating its adaptability. Finally, *Pyrobombus* species may respond differently in other parts of their range. For example, *B. ternarius* appears to be locally extirpated in Illinois (Grixti *et al.*, 2009) and significant declines in *B. vagans* populations have been documented in New Hampshire (Jacobson *et al.*, 2018).

Members of the *Cullumanobombus* subgenus also appear to be relatively stable or increasing. While this group appears to be stable in New York, *B. rufocinctus* populations have been shown to be negatively impacted by agricultural intensification in the Midwest (Hemberger *et al.*, 2021), and likely in other parts of its range. *Bombus griseocollis* and *B. rufocinctus* share similar traits including short tongues. They can nest either above or belowground (Williams *et al.*, 2014). Plasticity in nesting location

could allow greater adaptability to a changing landscape. Bumble bees have shown behavioral plasticity to ensure nest success and in response to climate change (Maebe *et al.*, 2021; Holland *et al.*, 2021). It is possible that bumble bee nests located aboveground are more susceptible to disturbance and weather extremes when compared to nests that are located underground where they may be more protected. While data on bumble bee nests are limited due to the challenge in locating them, Mullan (2022) found that aboveground nesting bumble bees may need to cool their nests at unsustainable levels in the face of warming temperatures.

Four species across two subgenera, *Thoracobombus* and *Bombus*, in New York have experienced drastic declines and have been more frequently detected with the *Vairimorpha bombi* (Microsporidia: Nosematidae) (=*Nosema bombi*; Tokarev *et al.*, 2020) pathogen (Cameron *et al.*, 2016), whose spillover into wild bumble bee populations in the 1990s caused rapid decline of *B. terricola* (S3), *B. affinis* (SH), *B. pensylvanicus* (S2), and *B. fervidus* (S3) (Colla *et al.*, 2006; Otterstatter & Thomson, 2008; Cameron *et al.*, 2016). These species showed higher levels of *V. bombi* infection (15–37%) when compared to non-declining species with low infection rates (<1%) (Cameron *et al.*, 2016). In particular, it appears that declines in *B. affinis* and *B. pensylvanicus* populations are correlated with higher pathogen loads and lower genetic diversity; however, without baseline data this hypothesis is challenging to confirm (Cameron *et al.*, 2011; Cordes *et al.*, 2012). While some of the affected species, such as *B. terricola* and *B. fervidus*, appear to have somewhat recovered, *B. affinis* and *B. pensylvanicus* have not. Apparent increases in status for *B. terricola* and *B. fervidus* could be due to increased survey effort and/or a recovery in the population post-*V. bombi* outbreak, but greater survey effort cannot explain the continued absence of *B. affinis* and rarity of *B. pensylvanicus*.

Cuckoo bumble bees (subgenus *Psithyrus* Lepeletier) appear to be the most threatened group of bumble bees in New York. Both *B. f. appalachiensis* (S2) and *B. citrinus* (S2S3) are considered rare and at-risk, and *B. bohemicus* (SH) and *B. insularis* (SH) are considered extirpated. Nearby states have seen similar declines (Northeast Fish and Wildlife Diversity Technical Committee, 2024). The status of cuckoo bumble bees is likely tied to host species declines (Lhomme & Hines, 2019). Cuckoo bumble bees are understudied, generally occur in lower abundance, and may also be more vulnerable to the effects of climate change due to a potential mismatch in emergence and colony establishment in the obligate host-parasite relationship (Bower *et al.*, 2023).

Although this was not a focus of our study, tongue length appears to be correlated to dietary preferences, which have been linked to population dynamics. In the northeast, bumble bee species richness and declines in abundance appear to be attributed to smaller dietary breadths and shorter activity periods (Bartomeus *et al.*, 2013). Goulson (2005) suggests that the loss of Fabaceae plants correlated with declines in the long-tongued bees that favor them, whereas short-tongued bees have a more generalized diet and fewer species in this group have experienced declines. Countering this, de Keyzer *et al.* (2016) concluded that more short-tongued bumble bee species were experiencing decline when compared to medium or long-tongued bees. Both long-tongued (*e.g.*, *B. auricomus*, *B. borealis*, and *B. pensylvanicus*) and short-tongued (*e.g.*, *B. terricola*) species have been described as having a narrow pollen diet and declining in the Midwest (Williams *et al.*, 2014; Wood *et al.*, 2019). Gibson *et al.* (2019) found that common bumble bee species forage on a wide range of floral resources and did not have an association with a particular flowering group, whereas at-risk bumble bee species (*B. fervidus*, *B. pensylvanicus*, *B. terricola*) had a significant association to plants in the family Fabaceae. More research is needed to determine whether tongue length is correlated with dietary breadth and decline or vulnerability.

Climate change can lead to a desynchronization between insects and their food plants (Forrest, 2016). Inferring phenological change from a large dataset of observation dates is challenging, and our analysis yielded mixed results. Four species

showed significantly later mean observation dates after the year 2000 and included the adaptable *B. impatiens* (S5) and three species that were assessed as Imperiled or Vulnerable: *B. fervidus* (S3), *B. terricola* (S3), and *B. citrinus* (S2S3). A single species, *B. perplexus* (S3), trended significantly earlier. Interestingly, *B. perplexus* is one of the species with colonies that end earliest in the summer (Williams *et al.*, 2014). Despite mixed findings, alternative metrics, such as earliest observation dates, may overemphasize the importance of occasional spring warm-ups. While we lack the data to address this in our region, tracking the dates of key moments in a colony's life cycle when it is most vulnerable (*e.g.*, the emergence of queens that have overwintered), in addition to floral availability, will further our understanding. Standardized species-specific phenological studies, while labor intensive, would vastly improve our understanding of *Bombus* activity in the modern era. Desynchronization could occur in various ways, primarily with shifts in either pollinator activity or floral resource phenology, or both. Indeed, Villagomez *et al.* (2021) found that while warmer temperatures can lead to an early spring and advanced floral phenology, warming temperatures did not result in earlier springtime bee activity. While the data are limited, our phenology analysis highlights the complexity of individual species responses, where some species are active (or at least detected) earlier on average and others later in the season than historically observed, with any of these changes potentially stressing the pollinator-resource relationship.

While climate change impacts vary by species, changes in temperature and precipitation have been identified as driving factors altering bumble bee community composition. A recent climate model predicted that more *Bombus* species will be negatively impacted by increasing temperatures than will benefit from them. Six of the nine species in the study showing negative impacts are known from New York and include *B. bohemicus* (SH), *B. borealis* (S3), *B. perplexus* (S3), *B. terricola* (S3), *B. ternarius* (S4S5), and *B. vagans* (S5), the majority of which were described as "cool-adapted" species (Jackson *et al.*, 2022). More warm-adapted bumble bee species have stable or increasing populations while more cool-adapted species have decreased in North America while temperatures have risen (Jackson *et al.*, 2022; Hemberger & Williams, 2024). An increase in precipitation had a positive effect on *B. impatiens* occupancy, while *B. rufocinctus* and *B. fervidus* had the strongest negative responses to increased precipitation (Jackson *et al.*, 2022). Perhaps coincidentally, both *B. rufocinctus* and *B. fervidus* nest at the surface or aboveground, potentially making these species more vulnerable to changing conditions and extreme weather events. There is a growing body of evidence that some species are more vulnerable to certain stressors than others (Colla *et al.*, 2012), resulting in differential responses at the species level (Jackson *et al.*, 2022).

Our four-year inventory, while expansive, could not document all occurrences of rare species. New species records continue to be found post-ESNPS; these records are not reflected in this analysis. The post-ESNPS records may warrant a rank review for *B. auricomus*, *B. f. appalachiensis*, and potentially other *Bombus* species. Additional inventory is needed to define the current distribution of New York's rarer bumble bees, including *B. auricomus*, *B. f. appalachiensis*, *B. pensylvanicus*, and *B. citrinus*. In addition, research is required to understand the habitat requirements and threats to these at-risk species, and to create appropriate management guidelines for their persistence in known locations.

In the meantime, because bees cannot quickly adapt to environmental changes (de Keyzer *et al.*, 2016), action to combat climate change is imperative. Recent studies addressing the impacts of climate change found that increased temperatures had negative impacts on the majority of bumble bee species studied (Jackson *et al.*, 2022). Climate change is also leading to shrinking and shifting of bumble bee distributions (Kerr *et al.*, 2015). This can cause phenological mismatch between bumble bees and their floral resources (Pyke *et al.*, 2016), as well as between cuckoo bumble bee species

and their hosts (Bower *et al.*, 2023). Land managers should incorporate available data into conservation planning. For example, a plant-pollinator network analysis found that *Aster* sp., *Trifolium pratense*, *Rhus glabra*, and *Heliopsis helianthoides* were used by the highest number of bumble bee species in the northeast (Jacobson *et al.*, 2018) and land managers could consider planting these species to enhance habitat for bumble bees. Habitat protection is essential for conservation efforts (Liczner & Colla, 2019). Many conservation and management actions could benefit bumble bees, including efforts to protect bumble bee populations from insecticides and minimizing contact between wild bumble bee populations and commercial bees to reduce competition and reduce pathogen exposure (Mallinger *et al.*, 2017; Page & Williams, 2023). All of these steps may help retain diversity within the genus *Bombus* and contribute to ecosystem resiliency in a rapidly changing world.

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## SUPPLEMENTAL MATERIAL

**Table S1.** Life history and tongue length morphology of New York's *Bombus* species, grouped by subgenus.
**Table S2.** Partner and museum data sources for each *Bombus* species compiled during the ESNPS.
**Appendix S1.** Species profiles for 18 species of bumble bees recorded from New York State during the ESNPS and available historical records.

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