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The bumble bees (Hymenoptera: Apidae: *Bombus*) of Arkansas, fifty years later

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Abstract. Many species of bumble bees (Hymenoptera: Apidae: *Bombus* Latreille) are declining throughout their ranges in North America, yet detecting population trends can be difficult when historical survey data are lacking. In the present study, contemporary data is compared to a 1965 survey to detect changes in bumble bee distributions throughout Arkansas. Using county-level records as a point of comparison to look for changes in state-wide occurrence among species over time, we find that state-level changes reflect national trends. Contemporary records of *Bombus* (*Pyrobombus*) *bimaculatus* Cresson and *B*. (*P*.) *impatiens* Cresson have more than tripled, while records for *B*. (*Thoracobombus*) *pensylvanicus* (De Geer) show a decline to 61% of historical levels. Although *B*. (*T*.) *fervidus* (Fabricius) has been reported infrequently in the state, misidentifications may have led to an overestimation of the state's species richness. In addition to an updated assessment of the bumble bees of Arkansas, we also provide new, localized information on the seasonal phenology and plant preferences of each species that can be used to guide conservation efforts.

INTRODUCTION

Many species of bumble bees (Hymenoptera: Apidae: *Bombus* Latreille) are declining throughout their historic ranges in both North America (Cameron *et al*., 2011; Colla *et al*., 2012) and Europe (Dupont *et al*., 2011; Fitzpatrick *et al*., 2007; Williams *et al*., 2009). Contemporary resampling techniques have provided evidence for bumble bee declines in Illinois (Grixti *et al*., 2009; Lozier & Cameron, 2009), Ontario, Canada (Colla & Packer, 2008), Denmark (Dupont *et al*., 2011), and Sweden (Bommarco *et al*., 2012).

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Few locations are fortunate enough to have detailed historical surveys of bumble bees, however, and other methods must be employed if historical data is to be used to determine the present status of vulnerable species. Detecting declines can be difficult, especially in regions that lack historical survey records with which to compare contemporary data.

The use of specimen records in museum holdings offers an alternative method of detecting change over time (Shaffer *et al*., 1998). Ideally, these studies use records collected throughout the entire range of a species and compare the geographic occurrence or relative abundances across time periods to identify population changes. However, declines may be heterogeneous across a species' range, and habitat-specific assessments may yield conservation recommendations that are easier to implement (Hunter & Hutchinson, 1994). Yet conservation planning in the United States often occurs at a local (state, county, or city) level delimited by political boundaries that are often independent of broad-scale habitats (Huber *et al*., 2010). Therefore, conservation managers might benefit more directly from local-scale assessments. Indeed, many states, including Arkansas, conduct localized assessments of species of interest and classify species according to their conservation status within the state. Often, the state-based conservation status differs from that of a species throughout its range (ARNC, 2014).

There are no known historic surveys of bumble bee abundance in Arkansas with which contemporary surveys can be compared. However, in 1965 Chandler and McCoy produced a survey of the bumble bees of Arkansas based on statewide collecting efforts and the University of Arkansas Arthropod Museum (UAAM) holdings at that time (Chandler & McCoy, 1965). The authors reported the counties in which each species was recorded but gave no quantitative indication of abundance. Here, we use county records as a point of comparison to look for changes in statewide occurrence among species over time. It is not uncommon for historical records to contain only county-level locality data, and a county-level-comparison approach has been used to detect declines in other organisms such as amphibians in California (Fisher & Shaffer, 1996). The declining status of many bumble bees from England was first detected using vice-county-level records (Williams, 1982). Szabo *et al*. (2012) also used a similar census-unit approach to determine the persistence of three species of *Bombus* throughout their ranges in North America.

In this work, we compare historical and contemporary Arkansas county records to determine the changes in statewide occurrence of bumble bees. Additionally, we provide updated taxonomic information and ecological details for each species recorded in Arkansas, including new, localized information on the seasonal phenology and plant preferences of each species that can be used to guide conservation efforts.

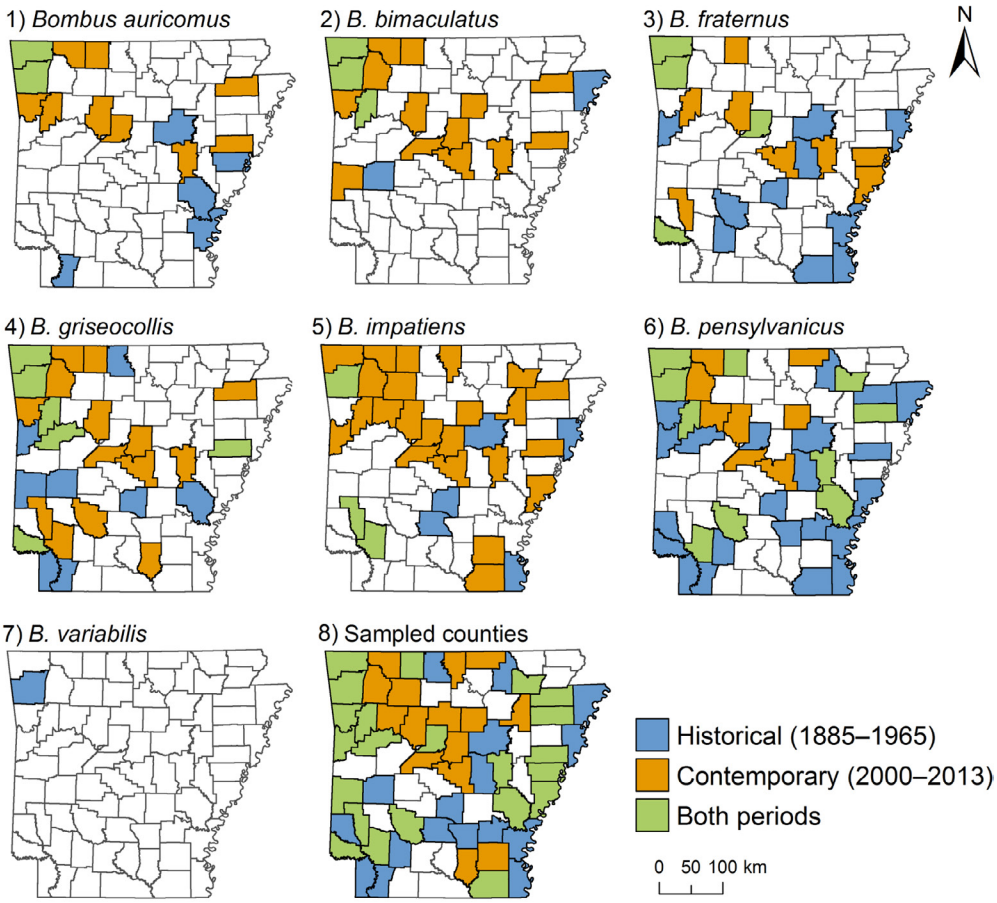
MATERIAL AND METHODS

The 75 counties of Arkansas range in size from 1411–2731 km^2, each with an average area of 1836 ± 335 km^2 (SD). New state distribution data for historical and contemporary periods were obtained from UAAM holdings (Fayetteville, Arkansas), specimens from citizen science volunteers, and our own collection efforts during 2010–2013. Specimens were identified to species using the keys and descriptions of Mitchell (1962) and Chandler & McCoy (1965), and vouchers were deposited in the UAAM. Because there was an obvious spatial bias in the dataset (*e.g*., 47% of specimens were collected from Washington County during the historical period), we chose to analyze these data using a new metric, proportion of occurrence, to standardize collection data across

the state. The proportion of occurrence of each species was determined as follows. Each bumble bee species was recorded as present or absent from each county in two periods: historical and contemporary. For each species, the number of counties with records of that species was divided by the total number of counties that were sampled for all species within that period to obtain a proportion of occurrence within each period. This differs from relative abundance measures in which all specimens are included as a single sample for each time period in that the sampling unit for our proportion of occurrence metric is one county. Thus, in this method multiple samples are taken for each time period, and disproportionately collected areas do not bias the species composition of the state as a whole. The historical period included all records through 1965, the publication date of the last Arkansas bumble bee survey (Chandler & McCoy, 1965). The contemporary period included all records in the period 2000–2013. This range was chosen to occur after the initial detection periods of decline for *Bombus* throughout North America [*e.g.*, 1988: *Bombus* (*Bombus*) *franklini* (Frison); late 1990s: *B.* (*B.*) *occidentalis* Greene; 1998: *B.* (*B.*) *affinis* Cresson; Committee on Status of Pollinators in North America (2007)]. Sampling effort within each of the time periods was compared by generating species accumulation curves for each period in the R (R Core Team, 2014) package vegan v.2.0-9 with 95% confidence intervals estimated using 1000 permutations of the data (Oksanen *et al.*, 2013). Changes in the statewide occurrence of each species were qualitatively assessed with comparisons of the proportion of sampled counties in which a species was observed for each period.

Natural history information for each species was determined from field surveys conducted every other week at 13 sites in Washington, Benton, Carroll, Boone, and Madison Counties in northwest Arkansas between March and October in 2010–2013. Surveys were conducted by a single observer in non-linear transect walks (Connop *et al.*, 2010; Silveira & Godínez, 1996) over 30-min increments during fair weather (12°C–39°C). All foraging individuals of *Bombus* were collected with an aerial net, and specimens were either identified in the field or retained as vouchers. Adult activity periods were determined from these surveys using adults of all castes combined. Both the extreme occurrences ("earliest" and "latest") and the dates encompassing 80% of observations ("majority") are reported. Species in which the majority active period begins before mid-summer (mid-June) are considered early-season species; those that begin after mid-summer are considered late-season species. Activity periods were then classified as short (<63 days), intermediate (63–77 days), or long (>77 days) based on equal intervals across the majority span of observations. Because of their ecological importance in food choice, the worker-glossa lengths of each species were also included. Following the recommendations of Harder (1982), glossal length (length of the glossa between the basal sclerite and the terminus of the flabellum) was deemed more representative of the functional tongue length of *Bombus*, and glossal measurements reported by Medler (1962) are reported as glossa lengths here. The average worker glossa length for each species was then categorized as short (<5.0 mm), medium (5.1–6 mm), or long (>6.0 mm). The plant species or genera encompassing at least 75% of nectar and pollen foraging observations of each species of *Bombus* over the survey period were noted as preferred plants, and these are listed in order of declining number of observations. Plant identifications to species were conducted in the field and with photographic vouchers using an Arkansas-specific key (Smith, 1994), known distributions (Kartesz & The Biota of North America Program, 2013), and a regional photographic field guide (Kurz, 2010). In some cases, identification to plant species was not possible, and these records were left at the level of genus (n=110, 9.6%).

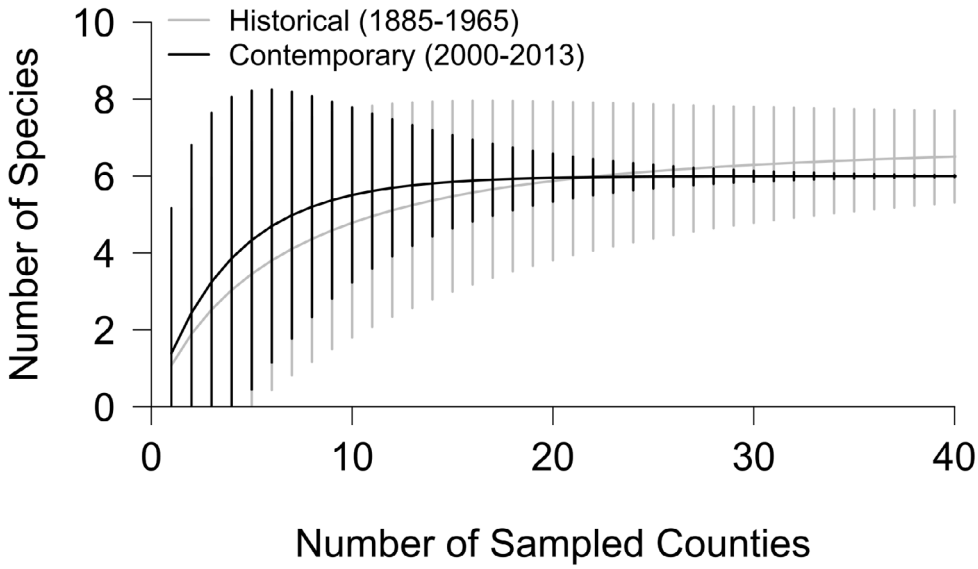
Figure 1. County-level records for each species in Arkansas and a summary of all records over both time periods. Blue = historical records, orange = contemporary records, and green = records for both periods. 1. *Bombus* (*Bombias*) *auricomus* (Robertson). 2. *B.* (*Pyrobombus*) *bimaculatus* Cresson. 3. *B.* (*Cullumanobombus*) *fraternus* (Smith). 4. *B.* (*C.*) *griseocollis* (De Geer). 5. *B.* (*P.*) *impatiens* Cresson. 6. *B.* (*Thoracobombus*) *pensylvanicus* (De Geer). 7. *B.* (*Psithyrus*) *variabilis* (Cresson). 8. Summary of all counties that were sampled within each period.



RESULTS

In total, 1620 specimens were examined, 219 from the historical period and 1293 from the contemporary period. The previous Arkansas survey yielded 68 records of seven species in 35 counties (Chandler & McCoy, 1965). All but nine of these records were represented in the UAAM, and an additional 13 county records from the historical period were obtained from UAAM holdings (years ranging from 1885–1965, n=217), adding records from four additional counties. Seven species: *Bombus* (*Bombias*) *auricomus* (Robertson), *B.* (*Pyrobombus*) *bimaculatus* Cresson, *B.* (*Cullumanobombus*) *fraternus* (Smith), *B.* (*C.*) *griseocollis* (De Geer), *B.* (*P.*) *impatiens* Cresson, *B.* (*Thoracobombus*) *pensylvanicus* (De Geer), and *B.* (*Psithyrus*) *variabilis* (Cresson), were recorded in 39 Arkansas counties throughout the historical period for a total of 81 county records.

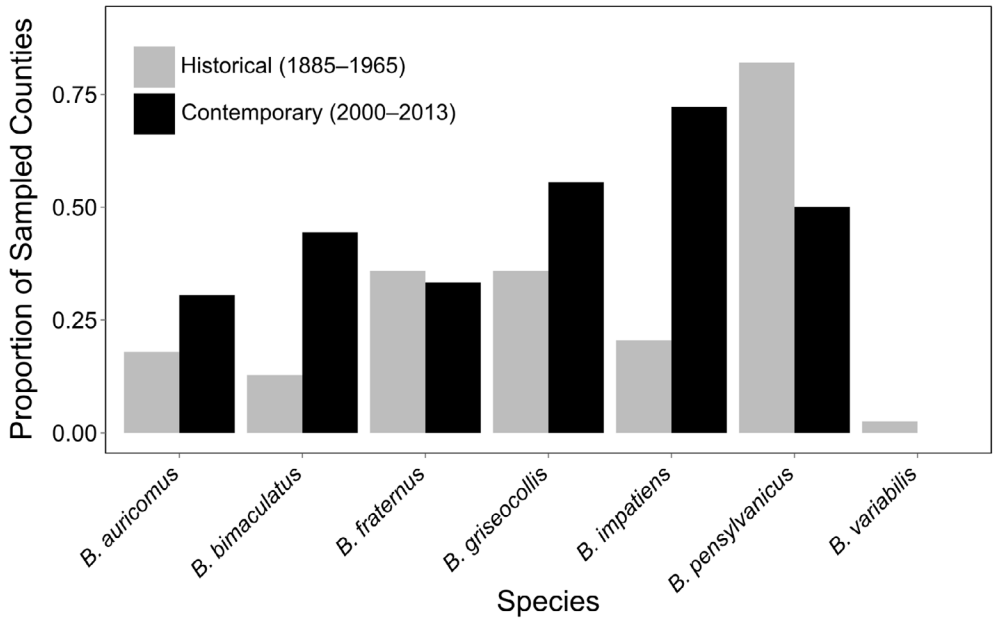
Figure 2. Species accumulation curves for each sampling period. Rarefied accumulation curves were calculated with each county serving as a single sample. Grey line=historical period, black line=contemporary period. Vertical lines represent 95% confidence interval estimates for each period, based on 1,000 permutations.



For the contemporary period (2000–2013), 92 records of six species in 36 counties were available. Of these, 28 were confirmations of historical records (*i.e.*, records of persistence), and 75 were new records of species in counties. All species observed in the historical period were observed in the contemporary period with the exception of *B. variabilis*. In both periods, all seven of Arkansas' Level III ecoregions (Woods *et al*., 2004) were sampled. Of the 108 specimens collected between our historical and contemporary periods (1966–1999), there were only seven novel county records, and each is listed in the species accounts that follow. The proportions of sampled counties with occurrences of each species within the historical and contemporary periods are shown in figure 1. Twenty-two of the 75 counties in Arkansas had no records from either period (Fig. 1). Two anomalous records of western species were among the specimens deposited in UAAM: *B. occidentalis* and *B.* (*P.*) *vosnesenskii* Radoszkowski, both collected in the 1980s in Washington County by the same collector. Because this collector had also deposited specimens from the western United States, where these species are found, we assume that these were mislabeled, rather than truly collected so far out of their natural range. Although the species *B.* (*T.*) *fervidus* (Fabricius) has been reported as occurring in the state (Chandler & McCoy, 1965; Franklin, 1912; Warriner, 2011) we found no evidence of its presence in Arkansas. This is discussed further in the section on *B. fervidus* below.

Sampling effort differed between the historical and contemporary periods as evidenced by rarefied species accumulation curves (Fig. 2). These curves show the number of species recorded as a function of the number of sampled counties and are constructed by randomly resampling the data (n = 1000 samples). Adequate sampling is expected to result in a flattened curve, while curves with a steep gain reflect data

Figure 3. Proportions of sampled counties (*i.e.*, proportions of occurrence) with records of each bumble bee species, in the historical (grey) and contemporary (black) periods in Arkansas.



that are under sampled. Sampling did not reach an asymptote in the historical period, suggesting that the state may have been under sampled during this period. During the contemporary period, species richness showed an asymptote early within the number of sampled counties, indicating that the sampling effort was sufficient to capture statewide species richness.

Most species showed an increase in proportion of occurrence between the historical period and the contemporary period (Fig. 3). *Bombus bimaculatus* and *B. impatiens* occurrence records increased three-fold, *B. auricomus* nearly doubled, and *B. griseocollis* showed an increase of about one third. *Bombus fraternus* remained virtually unchanged. *Bombus pensylvanicus* occurrence records decreased by 39%. *Bombus variabilis* was not recorded in any counties in the contemporary period.

DISCUSSION

Establishing whether or not species are declining or stable is a challenge for species that are rare throughout their ranges such as *B. fraternus* and *B. variabilis*. Both of these species have been the focus of conservation attention in range-wide assessments (*e.g.*, Colla *et al.*, 2012; Williams *et al.*, 2014). However, one of the issues inherent in detecting declines of rare species is the difficulty in accurately detecting the presence of rare species during surveys. The relative rarity of *B. fraternus* provides a good example of how measures of persistence, *i.e.*, site-specific confirmations of the presence, of an uncommon species might lead to erroneous conclusions about the local conservation status of a species. Measures of persistence assume that the absence of a species during a resampling effort is a true absence, an assumption that may not hold if the species is rare, sparsely distributed, cryptic, or simply less

detectable than other species (Kery, 2004). In this study, only four of the 14 historical county records of *B. fraternus* were confirmed with contemporary records. With only four confirmation records out of the seven counties resampled in the contemporary period, this species would have a statewide persistence value of 57%, yet the proportion of sampled counties in which it occurred statewide remained unchanged between the two periods. An analysis of contemporary persistence at particular localities based on confirmations would indicate a decline, yet our analysis of county-level occurrence suggests that there has been little change in the species within the state. Although *B. fraternus* is widely distributed throughout the southeastern and midwestern United States, its relative rarity seems consistent throughout its range (Williams *et al*., 2014). Specimens of *B. fraternus* accounted for 3.5% of all specimens of *Bombus* in the UAAM collection. Over all time periods, the relative abundance of *B. fraternus* remained below 1% in a survey of museum records of all *Bombus* occurring in the eastern United States (Colla *et al*., 2012). Similarly, *B. fraternus* accounted for less than 2% of all records of *Bombus* in Illinois, regardless of the sampling period (Grixti *et al*., 2009). Rare species are often the center of conservation attention, but detecting declines in such species will require novel approaches to overcome innate statistical difficulties (Strayer, 1999).

Although we have used an alternative method of assessing the conservation status of bumble bees in Arkansas, the trends we have observed largely agree with those seen in other studies. The number of county records of *B. bimaculatus* and *B. impatiens* has more than tripled between the historic and contemporary periods, while the number of county records of *B. pensylvanicus* has declined to 61% of historical levels (Fig. 3). These changes are consistent with surveys across eastern North America that have examined these three species using relative abundance methods. Rather than comparing the proportion of samples in which a species is present as we have done here, relative abundance methods compare the percentage of specimens that belong to each species of interest out of the total number of individuals in a sample. For example, Cameron *et al*. (2011) found that among sampled species, the proportions of specimens of both *B. bimaculatus* and *B. impatiens* nearly doubled between historical (1900–1999) museum records and contemporary (2007–2009) sample periods. In a comparison of 14 species in Ontario, Canada, the relative abundances of *B. bimaculatus* and *B. impatiens* more than doubled between surveys in the early 1970s and those in the mid-2000s; *B. pensylvanicus* was not present at all in the later survey (Colla & Packer, 2008). Similarly, in a study of 21 eastern North American species that compared historical (1864–1990) and contemporary (1991–2009) museum records, *B. bimaculatus* and *B. impatiens* were persistent at sites throughout their ranges and exhibited an increase in relative abundance, while *B. pensylvanicus* was absent from 66% of its former range, although it showed no change in relative abundance (Colla *et al*., 2012). Our county-level, proportion of occurrence data show that in Arkansas, *B. bimaculatus*, *B. impatiens*, and *B. pensylvanicus* exhibit the same temporal trends that have been observed throughout their ranges.

Species-level differences in ecological characteristics and requirements may help explain why some species are faring well, while others are declining. Late colony initiation times and long tongues have been cited as characteristics shared among some declining species, particularly in Europe (Bommarco *et al*., 2010; Dupont *et al*., 2011), but also in North America (Colla *et al*., 2012; see also Williams *et al*., 2009, for a meta-analysis that also includes China). Late season species of *Bombus* have less time to grow their colonies to the size necessary to produce new reproductives before the

end of the season. This can leave species with long activity periods particularly vulnerable to colony failure before next season's reproductives are produced (Williams *et al*., 2009). Of the three species with late activity times in Arkansas, *B. impatiens* has increased, *B. pensylvanicus* has decreased, and *B. fraternus* has not changed between the historical and contemporary periods (Fig. 3). Both *B. pensylvanicus* and *B. fraternus* have long active periods as well (82 and 92 days, respectively). Species that require a lengthy period of stable floral resources to successfully rear reproductives might be more vulnerable to colony failure during seasonal fluctuations in habitat quality (Williams *et al*., 2009). Bees with longer glossae are thought to have more specialized diets, leaving them more susceptible to changes in floral assemblages that accompany land-use changes (Goulson *et al*., 2005). The two long-tongued species in Arkansas are the somewhat uncommon *B. auricomus* and the purportedly declining species *B. pensylvanicus*. The only species that has experienced a decline in county-level occurrence in Arkansas is *B. pensylvanicus*, a late-season, long-glossa species with a long active period. This supports the hypothesis that the interaction between these factors may predispose some bumble bee species to decline (Williams *et al*., 2009).

For each species that occurs in Arkansas, we report the local phenology, tongue length, and plant preferences in the species accounts that follow. Classifying tongue lengths was deemed necessary in order to match the qualitative designations of tongue length used in other bumble bee literature (*e.g*., Colla *et al*., 2011; Kearns & Thomson, 2001). This is especially important considering that some studies include the length of the prementum in measuring tongue length (Goulson & Darvill, 2004), rendering comparisons between absolute measurements incompatible.

Knowledge of the phenology of Arkansas bumble bee species should aid monitoring efforts for species of conservation interest locally by allowing conservation managers to time sampling efforts appropriately for each species of interest. Knowing which plants are regionally preferred can inform targeted monitoring efforts, as well. The plant preferences listed here can be used as a guide for those interested in increasing bumble bee habitat in the region, particularly in the Ozark ecoregion in northwest Arkansas, northeastern Oklahoma, and southwestern Missouri. For example, we found that the wild indigoes, *Baptisia alba* (Linnaeus) Ventenat and *B. bracteata* Muhl. ex Elliott (Fabaceae), are preferred by both *B. auricomus* and *B. pensylvanicus*, the two long-glossa species in the state. No single plant species was preferred by all species, but some were common enough among multiple bumble bee species to be highly recommended for bumble bee forage plots. A planting of *Silphium integrifolium* Michx. (wholeleaf rosinweed, Asteraceae), *Monarda fistulosa* Linnaeus (wild bergamot, Lamiaceae), and *Teucrium canadense* Linnaeus (Canada germander, Lamiaceae) should appeal to all six species of *Bombus* for which plant-preference data were gathered. All but five of the plants most preferred by *Bombus* in Arkansas [*Abelmoschus esculentus* (Linnaeus) Moench (okra, Malvaceae), *Carduus nutans* Linnaeus (nodding plumeless thistle, Asteraceae), *Centaurea stoebe* Linnaeus (spotted knapweed, Asteraceae), *Vicia sativa* Linnaeus (garden vetch, Fabaceae), and *V. villosa* Roth (winter vetch, Fabaceae)] are native to the area and could be considered when planning pollinator habitat areas.

SPECIES ACCOUNTS

The following accounts provide details for each species that has been recorded in Arkansas. The common names of bumble bees are taken from the Entomological

Society of America database of Common Names of Insects and Related Organisms (Entomological Society of America, 2014), while those of plants are from the United States Department of Agriculture PLANTS Database (United States Department of Agricuture National Resources Conservation Service, 2014). Glossa lengths are provided by Medler (1962). Data on periods of adult activity and preferred host plants are from observations in northwest Arkansas as outlined in the methods section.

Bombus (*Bombias*) *auricomus* (Robertson)
'Black & Gold Bumble Bee'

Bombus auricomus was not listed as occurring in Arkansas in Franklin's (1912) account of the bumble bees of the New World, but was recognized as *B. nevadensis auricomus* in seven counties in Chandler & McCoy's (1965) statewide account (Fig. 1). *Bombus auricomus* and its close relative in the west, *B.* (*B.*) *nevadensis* Cresson, are currently thought of as separate species (Cameron *et al*., 2007; Scholl *et al*., 1992). *Bombus auricomus* is the longest-glossa bumble bee in the state, but it is an early-season species compared to others in the area. It has a relatively short active period and is among the rarer species in the state (7% of specimens of *Bombus* in the UAAM collection). In northwest Arkansas, *B. auricomus* is one of the earliest species to establish colonies, and these colonies are typically completed by early July. In other areas of its range, *B. auricomus* seems to follow a different seasonal schedule. The species is a late-season species relative to other species in Ontario (Colla & Dumesh, 2010) and a mid-season species in Alberta (Hobbs, 1965). In Virginia, males were still actively seeking mates in mid-August (Alcock & Alcock, 1983), suggesting that colonies in Virginia persist much later than they do in Arkansas. The distribution of *B. auricomus* in North America seems to be primarily north of Arkansas. Indeed, the southern half of Arkansas is not included in recent range maps of the species (Colla *et al*., 2011; Williams *et al*., 2014), although historic records of its occurrence are known (Fig. 1). Although uncommon throughout the state, the occurrence of *B. auricomus* has increased between the historic (18%) and contemporary periods (31%, Fig. 3).

Bombus auricomus has garnered some conservation attention of late. Throughout North America, *B. auricomus* persists in less than 50% of its historic range, but its relative abundance appears unchanged (Colla *et al*., 2012). In Arkansas, the presence of *B. auricomus* in the extreme southwestern region of the state was not confirmed in recent surveys of the Blackland Prairie remnants, prompting some concern for its status in the region (Warriner, 2011). In the central portion of its range in Illinois, contemporary surveys show that *B. auricomus* is as widely distributed and abundant today as in the past (Grixti *et al*., 2009). As with species like *B. fraternus* and *B. variabilis*, the relative rarity of *B. auricomus* in some areas of its distribution renders collection records inconsistent and creates a challenge for comparative studies seeking to establish the conservation status of this species.

Glossa length: Long (7.12 ± 0.39 mm).

Adult active period: Early season with a short active period (58 days). Majority: mid-May through early July; Earliest: April 18; Latest: August 11.

Preferred plants: *Monarda fistulosa* (wild bergamot, Lamiaceae), *Baptisia alba* (white wild indigo, Fabaceae), *B. bracteata* (longbract wild indigo, Fabaceae), *Penstemon digitalis* Nutt. ex. Sims. (foxglove beardtongue, Plantaginaceae), *Pycnanthemum tenuifolium* Schrad. (narrowleaf mountainmint, Lamiaceae).

Bombus (*Pyrobombus*) *bimaculatus* Cresson
'Two-spotted Bumble Bee'

Bombus bimaculatus is, along with *B. auricomus*, one of the earliest species to become active in Arkansas. It also has the shortest active period in northwest Arkansas, with the majority of individuals spotted over a period of only 48 days. Although Chandler & McCoy (1965) stated that they observed this species in the state during late summer and early fall, only three of 214 specimens of *B. bimaculatus* in the UAAM collection were collected after July. These were collected in 1964 and 1976, and all were from Washington County. In spite of its short active period, the proportion of counties with records of *B. bimaculatus* increased dramatically from 13% of sampled counties in the historic period to 44% in the contemporary period (Fig. 3). *Bombus bimaculatus* showed a strong preference for non-native vetch species, with 64% of all specimens observed on *V. sativa* and *V. villosa*. Vetches have been naturalized through much of the southeastern North America and are often grown as forage and cover crops, and for erosion control (Owsley, 2011). Perhaps their ability to use novel plant resources has contributed to the increased presence of *B. bimaculatus* in Arkansas, although other studies have also reported recent increases in *B. bimaculatus* throughout its range (Cameron *et al*., 2011; Colla & Packer, 2008; Colla *et al*., 2012).

GLOSSA LENGTH: Medium (5.65 ± 0.64 mm).

ADULT ACTIVE PERIOD: Early season with a short active period (48 days). Majority: mid-May through late June; Earliest: April 22; Latest: August 1.

PREFERRED PLANTS: *Vicia villosa* (winter vetch, Fabaceae), *V. sativa* (garden vetch, Fabaceae), *P. digitalis* (foxglove beardtongue, Plantaginaceae), *T. canadense* (Canada germander, Lamiaceae).

Bombus (*Thoracobombus*) *fervidus* (Fabricius)
'Yellow Bumble Bee'

Franklin (1912) reported *B. fervidus* as absent throughout "the greater part of Arkansas", but, lacking deposited specimens, its presence could not be confirmed by Chandler & McCoy (1965). Although *B. fervidus* has intermittently been reported in the state (Franklin, 1912; Warriner, 2011), and niche modeling suggests that the northwestern portion of the state could be marginally suitable for the species (Williams *et al*., 2014), its presence here is dubious. A recent survey of *Bombus* in remnant grasslands throughout the state reported *B. fervidus* in Boone and Franklin Counties in 2003 (Warriner, 2011), the first such sightings since it was reported 90 years prior (Franklin, 1912). The Boone County specimen was the only state record of this species with a deposited voucher specimen. Another historical specimen identified as *B. fervidus* is among the specimens in the UAAM collection: a male collected October 1, 1963 in Columbia County in the southern extreme of the state. These two specimens deposited in the UAAM collection as *B. fervidus* were both males, yet investigations of genitalic characters by the authors revealed that they are actually *B. pensylvanicus*.

Males of *B. fervidus* superficially resemble some of the variants of male *B. pensylvanicus*, and the two species can be difficult to distinguish (Mitchell, 1962). Although Mitchell (1962) suggests a number of external characters that can be helpful, *B. pensylvanicus* and *B. fervidus* males can only be reliably distinguished by comparing their genitalia. The most obvious difference is in the penis valves (*sensu* Michener, 2007; Mitchell, 1962). The enlarged apices of the penis valves of *B. pensylvanicus* are

long and slender, while the apices of those of *B. fervidus* are more truncate, with the breadth and width about equal. Additionally, the interior process of the gonostylus of *B. pensylvanicus* is flattened and broad, unlike that of *B. fervidus*. *Bombus fervidus* was not observed in 2011–2013 standardized surveys that we conducted throughout the northwestern portion of Arkansas, despite intensive sampling each season (number of observations = 1693). The North American distribution of *B. fervidus* appears to be primarily western and northeastern (Koch *et al*., 2012; Williams *et al*., 2014). To date, there are no deposited specimens of *B. fervidus* collected in Arkansas. Although we cannot discount its occasional presence in Arkansas, it seems more likely that records of this species in Arkansas are based on misidentifications of males, rather than true occurrences. The Arkansas Natural Heritage Commission lists *B. fervidus* as a species of concern within the state, with a ranking of S1, an "extremely rare" species at risk of statewide extirpation, known from Boone and Franklin Counties (ARNC, 2014). Investing in the conservation of species that are not true residents of an area, such as vagrants or marginal species (*i.e*., ones that occasionally occur in an area at the extreme of the species' range margin) is an inefficient approach to conservation that squanders scarce resources (Rodrigues & Gaston, 2002). Because there are no vouchered specimens of this species collected in Arkansas, we recommend that this state ranking be re-assessed.

Glossa length: Long (6.50 ± 0.74 mm).

Adult active period: Not in the state.

Preferred plants: Unknown.

Bombus (*Cullumanobombus*) *fraternus* (Smith)
'Southern Plains Bumble Bee'

In their museum survey, Chandler & McCoy (1965) noted *B. fraternus* as "widespread", and it was recorded in as many counties as *B. griseocollis* (Fig. 3). *Bombus fraternus* remains widely distributed across Arkansas, and its occurrence has remained stable between the historic (36%) and contemporary periods (33%, Fig. 3). Although *B. fraternus* appears to have a wide geographic distribution, it is relatively less abundant than its congeners (Colla *et al*., 2012; Grixti *et al*., 2009). There are some indications that *B. fraternus* may be declining and the International Union for Conservation of Nature has classified the species as endangered (Hatfield *et al*., 2014), but its relative rarity makes it difficult to be certain of its status. Throughout its range, *B. fraternus* has declined in relative abundance and in geographic persistence, but its relative abundance over all museum records was only 0.32% (Colla *et al*., 2012). Similarly, an Illinois study designated *B. fraternus* as declining after finding that it was absent from the southern region of the state where it was formerly present, but its relative abundance ranged from 0.2–1.9% over all studied records spanning 1900 to 2007 (Grixti *et al*., 2009).

Glossa length: Short (4.69 ± 0.37 mm).

Adult active period: Late season with a long active period (92 days). Majority: early July through early October; Earliest: April 6; Latest: October 3.

Preferred plants: *Passiflora incarnata* Linnaeus (purple passionflower, Passifloraceae), *S. integrifolium* (wholeleaf rosinweed, Asteraceae), *Solidago* Linnaeus (goldenrod, Asteraceae), *Liatris pycnostachya* Michx. (prairie blazing star, Asteraceae), *Silphium* Linnaeus (rosinweed, Asteraceae), *Bidens aristosa* (Michx.) Britt. (bearded beggarticks, Asteraceae), *Cephalanthus occidentalis* Linnaeus (common buttonbush, Rubiaceae), *Solidago altissima* Linnaeus (Canada goldenrod, Asteraceae), *Verbesina virginica* Linnaeus (white crownbeard, Asteraceae).

Bombus (*Cullumanobombus*) *griseocollis* (De Geer)
'Brown-belted Bumble Bee'

Bombus griseocollis is a widely distributed species in both eastern and western North America (Koch *et al*., 2012; Williams *et al*., 2014). Within Arkansas, the occurrence of *B. griseocollis* has greatly increased between the historic (36%) and contemporary periods (56%, Fig. 3). Two specimens in UAAM were captured in the period between the sampling periods in this study: Johnson Co., July, 1978 and Cleburne Co., April 19, 1969.

GLOSSA LENGTH: Short (4.91 ± 0.50 mm).

ADULT ACTIVE PERIOD: Early season with a short active period (60 days). Majority: early June through early August; Earliest: April 18; Latest: October 15.

PREFERRED PLANTS: *Cephalanthus occidentalis* (common buttonbush, Rubiaceae), *P. tenuifolium* (narrowleaf mountainmint, Lamiaceae), *T. canadense* (Canada germander, Lamiaceae), *L. pycnostachya* (prairie blazing star, Asteraceae), *C. nutans* (nodding plumeless thistle, Asteraceae), *Asclepias hirtella* (Pennell) Woodson (green milkweed, Apocynaceae), *A. viridis* Walter (green antelopehorn, Apocynaceae), *V. villosa* (winter vetch, Fabaceae), *Centaurea stoebe* Lam. (spotted knapweed, Asteraceae), *M. fistulosa* (wild bergamot, Lamiaceae), *S. integrifolium* (wholeleaf rosinweed, Asteraceae).

Bombus (*Pyrobombus*) *impatiens* Cresson
'Common Eastern Bumble Bee'

The occurrence of *B. impatiens* has more than tripled between the historic (21%) and contemporary sample periods (72%, Fig. 3). This is consistent with other reports of *B. impatiens* throughout its range (Cameron *et al*., 2011; Colla & Packer, 2008; Colla *et al*., 2012). The UAAM collection holds two specimens collected between our historical and contemporary periods: Polk Co., June 4, 1963 and Saline Co., August 17, 1976. In the United States, *B. impatiens* is the only bumble bee species currently mass-reared for pollination services and has been commercially available since 1990 (Velthuis & van Doorn, 2006). The ecological repercussions of commercial bumble bee trafficking are largely unknown. The greatest concern has been the potential for pathogen spillover, the transmission of diseases from commercial colonies to wild ones. Commercial bumble bee colonies are known to support heavier loads of pathogens, such as the intestinal protozoa *Crithidia bombi* Lipa & Triggiani and *Nosema bombi* Fantham & Porter, and parasites, such as the tracheal mite *Locustacarus buchneri* (Stammer), than their wild counterparts (Colla *et al*., 2006). Wild bees foraging near greenhouses in Canada which utilize commercial bumble bees are more likely to be infected with *C. bombi* and *N. bombi* than wild bees located far from greenhouses (Colla *et al*., 2006). This pathogen spillover from commercial bumble bees to wild populations may pose a threat to the stability of wild bumble bee populations. The commercial use of *B. impatiens* may also have another potential ecological impact that has remained unexplored: artificially increasing the local abundance of the commercial species through augmentation. If this were the case, we might expect *B. impatiens* to be less common in wildlands than in areas near agricultural development. Indeed, *B. impatiens* was rarely encountered in surveys of Arkansas grasslands from 2002 to 2008 (Warriner, 2011), in spite of its recent increase in county-level records. Whether or not the commercial trafficking of *B. impatiens* has influenced localized increases in Arkansas and elsewhere is unknown, but it is a notion that warrants further study.

Glossa length: Short (4.74 ± 0.62 mm).

Adult active period: Late season with an intermediate active period (75 days). Majority: mid-July through early October; Earliest: April 22; Latest: October 20.

Preferred plants: *Solidago speciosa* Nutt. (showy goldenrod, Asteraceae), *Symphyotrichum* Nees (aster, Asteraceae), *S. integrifolium* (wholeleaf rosinweed, Asteraceae), *Solidago* (goldenrod, Asteraceae), *P. pilosum* (Michx.) Pers. (whorled mountainmint, Lamiaceae), *V. alternifolia* (Linnaeus) Britt. ex Kearney (wingstem, Asteraceae), *V. virginica* (white crownbeard, Asteraceae), *S. altissima* (Canada goldenrod, Asteraceae), *Salvia azurea* Michx. ex Lam. (azure blue sage, Lamiaceae).

Bombus (*Thoracobombus*) *pensylvanicus* (De Geer)
'American Bumble Bee'

Bombus pensylvanicus [as *B. americanorum* (Fabricius)] was listed as the "most widespread and common species" in the state in Chandler & McCoy's (1965) study. Its statewide occurrence is much reduced today, although it remains widespread (Fig. 1). The contemporary occurrence of *B. pensylvanicus* (50%) is about one-third lower than its historic occurrence (82%, Fig. 3). Only a single record occurred in the period between our sampling intervals: Faulkner Co., September 6, 1976. This state-level pattern reflects what has also been observed throughout the range of *B. pensylvanicus*, and many sources consider *B. pensylvanicus* to be a declining species (Cameron *et al*., 2011; Colla & Packer, 2008; Colla *et al*., 2012; Grixti *et al*., 2009). Although there are indications of a range-wide decline of *B. pensylvanicus*, it is likely that not all areas are reflecting the same shifts in abundance or occurrence. For example, *B. pensylvanicus* was abundant in the extreme south and western portions of its range (Louisiana, Oklahoma, and Texas) in recent surveys, although it was absent from much of the northern and eastern areas in which it was expected to occur (Cameron *et al*., 2011). Similarly, *B. pensylvanicus* was absent from the northern region of Illinois in recent surveys, although it was known from northern Illinois in historical records (Grixti *et al*., 2009). With contemporary records occurring throughout the state and in each ecoregion, we found no geographic pattern in the occurrences of *B. pensylvanicus* within Arkansas. This heterogeneity among regional studies highlights the utility of localized studies in determining the conservation status of species of interest.

Glossa length: Long (6.41 ± 0.58 mm).

Adult active period: Late season with a long active period (82 days). Majority: late June through mid-September; Earliest: May 13; Latest: October 16.

Preferred plants: *Baptisia alba* (wild white indigo, Fabaceae), *Vernonia* Schreb. (ironweed, Asteraceae), *T. canadense* (Canada germander, Lamiaceae), *M. fistulosa* (wild bergamot, Lamiaceae), *A. esculentus* (okra, Malvaceae), *Solanum carolinense* Linnaeus (Carolina horsenettle, Solanaceae), *Cirsium discolor* (Muhl. ex Willd.) Spreng. (field thistle, Asteraceae), *S. azurea* (azure blue sage, Lamiaceae), *S. integrifolium* (wholeleaf rosinweed, Asteraceae), *V. villosa* (winter vetch, Fabaceae).

Bombus (*Psithyrus*) *variabilis* (Cresson)
'Variable Cuckoo Bumble Bee'

Prior to our examination, only a single record of this species in Arkansas existed in the literature. Chandler & McCoy (1965) listed a single record from Washington County, but without including any additional collection information. Three speci-

mens of *B. variabilis* collected in Washington Co. during our target historical period were among the specimens in the UAAM collection (September, 1900; August 15, 1906; October 1, 1961), yet no specimens for our contemporary period were present (Fig. 1). However, three additional male specimens that were collected outside of our historical and contemporary periods are present in the UAAM. Two specimens were collected in the northwest portion of the state (Franklin Co., October 5, 1976 and Washington Co., September 29, 1993); the other was collected in eastern Arkansas (Desha Co., August 7, 1966). *Bombus variabilis* was not recovered in our surveys or in Warriner's (2011) extensive Arkansas grassland surveys. With so few records, there is no suggestion of a change in the occurrence of *B. variabilis* between the historic (2.6%) and contemporary periods (0%, Fig. 3), and its status in the state remains unclear.

Records for this species are both temporally and spatially sporadic throughout eastern North America (Williams *et al*., 2014). The species is a member of the social parasite subgenus *Psithyrus* Lepeletier, whose host is *B. pensylvanicus*. Its unusual life history may help explain its rarity. Lacking a foraging worker caste, species of *Psithyrus* are nest-bound and less likely to be encountered in typical field surveys. Also, as obligate nest parasites, their abundance is bound to be lower than that of their host. Still, there are indications that *B. variabilis* is declining and deserves further study. Its host, *B. pensylvanicus*, is also suspected to be on the decline (Cameron *et al*., 2011; Colla *et al*., 2012), and an obligate parasite is likely to follow the same population trends as its host. Across its range, *B. variabilis* has dramatically declined both in abundance relative to other species of *Bombus* and in geographic persistence, leading to a recommendation that it be classified as "critically endangered" (Colla *et al*., 2012). As in the case of *B. fraternus*, we urge that studies aiming to determine the conservation status of this rarer species take into consideration the inherent difficulties in accurately sampling species with low detectability before drawing conclusions on its stability.

GLOSSA LENGTH: Unknown, not reported.

ADULT ACTIVE PERIOD: Unknown, records in Arkansas from August–September.

PREFERRED PLANTS: Unknown, not observed.

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