Journal of Melittology

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 statewide occurrence among species over time, we find that state-level changes reflect national trends. Contemporary *Bombus bimaculatus* and *B. impatiens* records have more than tripled, while *B. pensylvanicus* records show a decline to 61% of historical levels. Although *B. fervidus* has been infrequently reported 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.

KEY WORDS: *Bombus*, historical survey, contemporary survey, pollinator decline

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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). 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). Typically, 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). 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).

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 state-wide 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 state-wide 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 and colleagues (2012) also used a similar census-unit approach to determine the persistence of three *Bombus* species 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.

Materials and Methods

The 75 Arkansas counties range in size from 1411–2731 km2, each with an average area of 1836 ± 335 km2 (SD). 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. 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 *Bombus* decline throughout North America (*e.g*., 1988: *B. franklini* (Frison); late 1990s: *B. occidentalis* Greene; 1998: *B. affinis* Cresson, Committee on Status of Pollinators in North America, 2007). New state distribution data for both periods were obtained from UAAM holdings (Fayetteville, Arkansas), specimens from citizen volunteers and our own collection efforts during 2010–2013. Specimens were identified to species using the keys and descriptions of Mitchell (1962) and Chandler and McCoy (1965), and vouchers were deposited in the UAAM. 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 using 1,000 permutations (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 *Bombus* specimens were collected via 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-emerging species; those that begin after mid-summer are considered late-emerging 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 *Bombus* species 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%).

Results

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 auricomus* (Robertson)*, B. bimaculatus* Cresson*, B. fraternus* (Smith)*, B. griseocollis* (DeGeer)*, B. impatiens* Cresson*, B. pensylvanicus* (DeGeer) and*B. variabilis* (Cresson), were recorded in 39 Arkansas counties throughout the historical periodfor a total of 81 county records***.***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.* Only seven records captured information in the years between our historical and contemporary periods (1966–1999), and each is listed in the species accounts that follow. County-level occurrences of each species within the historical and contemporary periods are shown in Figure 1 (1–7). Twenty-two of the 75 counties in Arkansas had no records from either period (Fig. 1.8). Two anomalous records of western species were among the specimens deposited in UAAM: *B. occidentalis* and *B. 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. 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 *B. fervidus* section 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 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 county 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*. 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 may lead to erroneous conclusions about the local conservation status of a species. In this study, only four of the 14 historical county records of *B. fraternus* were confirmed with contemporary records, which would yield a persistence value of 29%, yet the number of 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 steep decline (>70%), 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). 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 *Bombus* records 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).

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 count data, relative abundance methods compare the percentage of samples that belong to each category of interest. For example, Cameron, *et al.* (2011) found that among sampled species, the percent of records 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 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 emergence 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). *Bombus* species with late emergence times 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 emergence 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* andthe purportedly declining species *B. pensylvanicus.* The only species that has experienced a decline in county-level occurrence in Arkansas is *B. pensylvanicus,* a late-emerging, 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.

The plant preferences listed here can be used as a guide for those interested in increasing bumble bee habitat in the region, particularly in northwest Arkansas, northeastern Oklahoma and southwestern Missouri. For example, we found that the wild indigoes, *Baptisia alba* and *Baptisia bracteata,* 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. A planting of *Silphium integrifolium* (wholeleaf rosinweed)*,* *Monarda fistulosa* (wild bergamot) and *Teucrium canadense* (Canada germander) should appeal to all six *Bombus* species for which plant preference data were gathered. All but five of the plants most preferred by *Bombus* in Arkansas (*Abelmoschus esculentus* (okra)*, Carduus nutans* (nodding plumeless thistle)*, Centaurea stoebe* (spotted knapweed)*, Vicia sativa* (garden vetch) and *V. villosa* (winter vetch)) 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 auricomus*, black and 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 and McCoy’s (1965) statewide account (Fig. 1.1). *Bombus auricomus* and its close relative in the west, *B. nevadensis,* 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-emerging species compared to others in the area. It has a relatively short active period and is among the rarer species in the state (8% of *Bombus* specimens 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-emerging 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. 1.1). 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 emerging 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)*, Baptisia alba* (white wild indigo)*, Baptisia bracteata* (longbract wild indigo)*, Penstemon digitalis* (foxglove beardtongue)*, Pycnanthemum tenuifolium* (narrowleaf mountainmint)

## *Bombus bimaculatus*, twospotted bumble bee:

*Bombus bimaculatus* is, along with *B. auricomus,* one of the earliest species to emerge in Arkansas. It also has the shortest active period, with the majority of individuals spotted over a period of only 48 days. In spite of its short active period, the number 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 *Vicia 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 emerging 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)*, Vicia sativa* (garden vetch)*, Penstemon digitalis* (foxglove beardtongue)*, Teucrium canadense* (Canada germander)

## *Bombus fervidus*, 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 and McCoy (1965). Although *B. fervidus* has intermittently been reported in the state (Franklin, 1912; Warriner, 2011), 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 author 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* 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 = 1,693). 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 literature records of this species in Arkansas are based on misidentifications, rather than true occurrences.

Glossa length: Long (6.50 ± 0.74 mm)

Adult active period: Not in the state

Preferred plants: Unknown

## *Bombus fraternus*, southern plains bumble bee:

In their museum survey, Chandler and 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, 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 emerging with a long active period (92 days). Majority: early July through early October; Earliest: April 6; Latest: October 3

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

*Bombus griseocollis*, brownbelted bumble bee:

*Bombus griseocollis* is a widely distributed species in both Eastern and Western North America (Koch*, et al.*, 2012; Williams*, et al.*, 2014). Although the species may be declining in the northeastern portion of its range (Williams*, et al.*, 2014), the occurrence of *B. griseocollis* has greatly increased between the historic (36%) and contemporary periods (56%, Fig. 3) within Arkansas. 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 emerging 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), *Pycnanthemum tenuifolium* (narrowleaf mountainmint)*, Teucrium canadense* (Canada germander)*, Liatris pycnostachya* (prairie blazing star), *Carduus nutans* (nodding plumeless thistle), *Asclepias hirtella* (green milkweed), *Asclepias viridis* (green antelopehorn), *Vicia villosa* (winter vetch)*, Centaurea stoebe* (spotted knapweed)*, Monarda fistulosa* (wild bergamot)*, Silphium integrifolium* (wholeleaf rosinweed)

## *Bombus impatiens*, 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* Gorunov and *N. bombi* Fantham and 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 emerging with an intermediate active period (75 days). Majority: mid-July through early October; Earliest: April 22; Latest: October 20

Preferred plants*: Solidago speciosa* (showy goldenrod), *Symphyotrichum* (aster)*, Silphium integrifolium* (wholeleaf rosinweed), *Solidago* (goldenrod), *Pycnanthemum pilosum* (whorled mountainmint)*, Verbesina alternifolia* (wingstem)*, Verbesina virginica* (white crownbeard)*, Solidago altissima* (Canada goldenrod)*, Salvia azurea* (azure blue sage)

*Bombus pensylvanicus*, American bumble bee:

*Bombus pensylvanicus* (as *B. americanorum* (Fabricius))was listed as the “most widespread and common species” in the state in Chandler and McCoy’s (1965) study. Its state-wide occurrence is much reduced today, although it remains widespread (Fig. 1.6). 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 north 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). This heterogeneity 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 emerging 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)*, Vernonia* (ironweed), *Teucrium canadense* (Canada germander), *Monarda fistulosa* (wild bergamot), *Abelmoschus esculentus* (okra), *Solanum carolinense* (Carolina horsenettle), *Cirsium discolor* (field thistle), *Salvia azurea* (azure blue sage), *Silphium integrifolium* (wholeleaf rosinweed), *Vicia villosa* (winter vetch)

## *Bombus variabilis*, variable cuckoo bumble bee:

Prior to our examination, only a single record of this species in Arkansas existed in the literature. Chandler and McCoy (1965) listed a single record from Washington County, but without including any additional collection information. Three specimens of *B. variablis* 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. 1.7). 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 nor 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).

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 cleptoparasitic subgenus *Psithyrus* whose host is *B. pensylvanicus.* Its unusual life history may help explain its rarity. Lacking a foraging worker caste, *Psithyrus* bumble bees 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 *Bombus* species 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

Acknowledgements

The authors would like to thank Jeffery Barnes (UAAM) for assistance and access to the collection, Clinton Trammel for specimens, as well as Barbara Lewis, Michael Warriner and volunteers throughout the state for providing additional specimens. This manuscript was greatly improved by inputs from a number of anonymous reviewers. We also wish to acknowledge the Arkansas Natural Heritage Commission for allowing access to statewide prairie sites (permit numbers S-NHCC-12-013 and S-NHCC-13-010) and Bob Caulk and the Fayetteville Natural Heritage Association for access to prairie restoration sites in the city of Fayetteville, Arkansas. This research was supported in part by the University of Arkansas, Arkansas Agricultural Experiment Station.

References

Alcock, J., & J.P. Alcock. 1983. Male behavior in two bumblebees, *Bombus nevadensis auricomus* and *B. griseocollis* (Hymenoptera: Apidae). *Journal of Zoology* 200(4): 561–570.

Bommarco, R., O. Lundin, H.G. Smith, & M. Rundlöf. 2012. Drastic historic shifts in bumble-bee community composition in Sweden. *Proceedings of the Royal Society B: Biological Sciences* 279(1727): 309–315.

Bommarco, R., J.C. Biesmeijer, B. Meyer, S.G. Potts, J. Pöyry, S.P. Roberts, I. Steffan-Dewenter, & E. Öckinger. 2010. Dispersal capacity and diet breadth modify the response of wild bees to habitat loss. *Proceedings of the Royal Society B: Biological Sciences* 277(1690): 2075–2082.

Cameron, S.A., H.M. Hines, & P.H. Williams. 2007. A comprehensive phylogeny of the bumble bees (*Bombus*). *Biological Journal of the Linnean Society* 91(1): 161–188.

Cameron, S.A., J.D. Lozier, J.P. Strange, J.B. Koch, N. Cordes, L.F. Solter, & T.L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. *Proceedings of the National Academy of Sciences* 108(2): 662–667.

Chandler, L., & C.E. McCoy, Jr. 1965. The bumble bees of Arkansas (Hymenoptera, Apidae, Bombinae). *Arkansas Academy of Science Proceedings* 19: 46–53.

Colla, S., L. Richardson, & P. Williams. 2011. *Bumble Bees of the Eastern United States*. FS-972; USDA Forest Service and the Pollinator Partnership; Washington, D.C.; 103 pp.

Colla, S.R., & L. Packer. 2008. Evidence for decline in eastern North American bumblebees (Hymenoptera: Apidae), with special focus on *Bombus affinis* Cresson. *Biodiversity and Conservation* 17(6): 1379–1391.

Colla, S.R., & S. Dumesh. 2010. The bumble bees of Southern Ontario: Notes on natural history and distribution. *Journal of the Entomological Society of Ontario* 141: 39–68.

Colla, S.R., M.C. Otterstatter, R.J. Gegear, & J.D. Thomson. 2006. Plight of the bumble bee: Pathogen spillover from commercial to wild populations. *Biological Conservation* 129(4): 461–467.

Colla, S.R., F. Gadallah, L. Richardson, D. Wagner, & L. Gall. 2012. Assessing declines of North American bumble bees (*Bombus* spp.) using museum specimens. *Biodiversity and Conservation* 21(14): 3585–3595.

Committee on Status of Pollinators in North America. 2007. *Status of pollinators in North America*. The National Academies Press; Washington, DC; 322 pp.

Connop, S., T. Hill, J. Steer, & P. Shaw. 2010. The role of dietary breadth in national bumblebee (*Bombus*) declines: Simple correlation? *Biological Conservation* 143(11): 2739–2746.

Dupont, Y.L., C. Damgaard, & V. Simonsen. 2011. Quantitative historical change in bumblebee (*Bombus* spp.) assemblages of red clover fields. *Plos One* 6(9): e25172.

Entomological Society of America. 2014. Common Names of Insects and Related Organisms Database. [<http://www.entsoc.org/pubs/common_names>; last accessed May, 2014].

Fisher, R.N., & H.B. Shaffer. 1996. The decline of amphibians in California’s Great Central Valley. *Conservation Biology* 10(5): 1387–1397.

Fitzpatrick, Ú., T.E. Murray, R.J. Paxton, J. Breen, D. Cotton, V. Santorum, & M.J. Brown. 2007. Rarity and decline in bumblebees: A test of causes and correlates in the Irish fauna. *Biological Conservation* 136(2): 185–194.

Franklin, H.J. 1912. The Bombidae of the new world. *Transactions of the American Entomological Society* 38(3/4): 177–486.

Goulson, D., & B. Darvill. 2004. Niche overlap and diet breadth in bumblebees; are rare species more specialized in their choice of flowers? *Apidologie* 35(1): 55–63.

Goulson, D., M.E. Hanley, B. Darvill, J.S. Ellis, & M.E. Knight. 2005. Causes of rarity in bumblebees. *Biological Conservation* 122(1): 1–8.

Grixti, J.C., L.T. Wong, S.A. Cameron, & C. Favret. 2009. Decline of bumble bees (*Bombus*) in the North American Midwest. *Biological Conservation* 142(1): 75–84.

Harder, L.D. 1982. Measurement and estimation of functional proboscis length in bumblebees (Hymenoptera: Apidae). *Canadian Journal of Zoology* 60(5): 1073–1079.

Hobbs, G. 1965. Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in Southern Alberta. II. Subgenus *Bombias* Robt. *The Canadian Entomologist* 97(2): 120–128.

Huber, P.R., S.E. Greco, & J.H. Thorne. 2010. Spatial scale effects on conservation network design: trade-offs and omissions in regional versus local scale planning. *Landscape Ecology* 25(5): 683–695.

Hunter, M.L., & A. Hutchinson. 1994. The virtues and shortcomings of parochialism: conserving species that are locally rare, but globally common. *Conservation Biology* 8(4): 1163–1165.

Kartesz, J.T., & The Biota of North America Program. 2013. North American Plant Atlas. [<http://www.bonap.org/napa.html>; last accessed May, 2014].

Kearns, C.A., & J.D. Thomson. 2001. *The Natural History of Bumblebees: A Sourcebook for Investigations*. University of Colorado Press; Boulder, CO; 130 pp.

Koch, J., J. Strange, & P.H. Williams. 2012. *Bumble Bees of the Western United States*. USDA Forest Service and the Pollinator Partnership; Washington, D.C.; 143 pp.

Kurz, D. 2010. *Arkansas Wildflowers*. Tim Ernst Publishing; Pettigrew, AR; 256 pp.

Lozier, J.D., & S.A. Cameron. 2009. Comparative genetic analyses of historical and contemporary collections highlight contrasting demographic histories for the bumble bees *Bombus pensylvanicus* and *B. impatiens* in Illinois. *Molecular Ecology* 18(9): 1875–1886.

Medler, J.T. 1962. Morphometric studies on bumble bees. *Annals of the Entomological Society of America* 55(2): 212–218.

Michener, C.D. 2007. *The Bees of the World*. John Hopkins University Press; Baltimore, MD; 992 pp.

Mitchell, T.B. 1962. *Bees of the Eastern United States II*. Technical Bulletin 152; North Carolina Agricultural Experiment Station; 557 pp.

Oksanen, J., F.G. Blanchet, R. Kindt, P. Legendre, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M. Henry, H. Stevens, & H. Wagner. 2013. *vegan*: Community Ecology Package. v.2.0-10. [[http://CRAN.R-project.org/package=vegan](http://CRAN.R-project.org/package%3Dvegan); last accessed May, 2014].

Owsley, M. 2011. *Plant fact sheet for hairy vetch (Vicia villosa)*. USDA-Natural Resources Conservation Service; Americus, GA; 2 pp.

R Core Team. 2014. R: A language and environment for statistical computing. v.3.1.0. [<http://www.R-project.org/>; last accessed May, 2014].

Scholl, A., R. Thorp, R. Owen, & E. Obrecht. 1992. Specific distinctiveness of *Bombus nevadensis* Cresson and *B. auricomus* (Robertson) (Hymenoptera: Apidae): Enzyme electrophoretic data. *Journal of the Kansas Entomological Society* 65(2): 134–140.

Shaffer, H.B., R.N. Fisher, & C. Davidson. 1998. The role of natural history collections in documenting species declines. *Trends in Ecology & Evolution* 13(1): 27–30.

Silveira, F.A., & L.M. Godínez. 1996. Systematic surveys of local bee faunas. *Melissa* 9: 1–4.

Smith, E.B. 1994. *Keys to the Flora of Arkansas*. University of Arkansas Press; Fayetteville, AR; 363 pp.

Strayer, D.L. 1999. Statistical power of presence-absence data to detect population declines. *Conservation Biology* 13(5): 1034–1038.

Szabo, N.D., S.R. Colla, D.L. Wagner, L.F. Gall, & J.T. Kerr. 2012. Do pathogen spillover, pesticide use, or habitat loss explain recent North American bumblebee declines? *Conservation Letters* 5(3): 232–239.

United States Department of Agricuture National Resources Conservation Service. 2014. The PLANTS Database. [<http://plants.usda.gov/java/>; last accessed August, 2014].

Velthuis, H.H.W., & A. van Doorn. 2006. A century of advances in bumblebee domestication and the economic and environmental aspects of its commercialization for pollination. *Apidologie* 37(4): 421–451.

Warriner, M.D. 2011. Bumblebees (Hymenoptera: Apidae) of remnant grasslands in Arkansas. *Journal of the Kansas Entomological Society* 84(1): 43–50.

Williams, P., S. Colla, & Z.H. Xie. 2009. Bumblebee vulnerability: Common correlates of winners and losers across three continents. *Conservation Biology* 23(4): 931–940.

Williams, P.H. 1982. The distribution and decline of British bumble bees (*Bombus* Latr.). *Journal of Apicultural Research* 21(4): 236–245.

Williams, P.H., R.W. Thorp, L.L. Richardson, & S.R. Colla. 2014. *Bumble Bees of North America: An Identification Guide*. Princeton University Press; Princeton, NJ; 208 pp.

**Figure Legends**

**Figure 1**. County-level records for each species in Arkansas showing historical (grey) and contemporary (dots), and a summary of all records. 1) *Bombus auricomus,* 2) *B. bimaculatus,* 3) *B. fraternus,* 4) *B. griseocollis,* 5) *B. impatiens,* 6) *B. pensylvanicus,* 7) *B. variabilis,* 8) Summary of all counties that were sampled within each period.

**Figure 2.** Species accumulation curves for each sampling period. Rarefied accumulation curves were calculated with each county serving as a single sample. Solid grey line = historical period, dashed black line = contemporary period.

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