SOUTHEASTERN POLLINATION STUDIES

by

ATHENA RAYNE ANDERSON

(Under the Direction of C. Ronald Carroll)

ABSTRACT

Pollinators are important to the human food supply and maintenance of healthy ecosystems. This dissertation explores the life history of two pollinating bee groups in the southeastern USA, and the use of social media for educating the public about pollinators. In the first chapter, the author examined the pollen preference of bees in the genus *Svastra*, and found that they carried only sunflower pollen (*Helianthus*) in Georgia. Implications for use of these bees in commercial sunflower production is discussed. In the second chapter, the author recorded the seasonal activity patterns of bumble bees (*Bombus*) in Georgia. Six bumble bee species were detected, with phenologies that differed across sites, years, and species. Phenological shifts between bees in this study and conspecifics studied in Canada are discussed, as well as suggestions for future research. In the final chapter, the author demonstrated the benefit of integrating several social media platforms on a website about pollinators. The author discusses the ease and benefits of using social media in outreach programs.

INDEX WORDS: *Svastra*, Pollen fidelity, Phenology, Bumble bee, Social media, Pollinators

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A Dissertation Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

DOCTOR OF PHILOSOPHY

ATHENS, GEORGIA

2012

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ACKNOWLEDGEMENTS

This dissertation would not have been possible without the support of friends and family. The author also thanks Ron Carroll, Keith Delaplane, Jim Affolter, Laurie Fowler, Jim Porter, and Cathy Pringle for their guidance during this research. Many thanks to the owners and staff of Durham Horticulture Farm, Spring Valley EcoFarms, Woodland Gardens, and Roots Farm for allowing the use of their sites. This research was partially funded by a Sigma Xi Grant in Aid of Research.

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CHAPTER 1

NOTES ON *SVASTRA* POLLEN FIDELITY IN THE SOUTHEASTERN USA

Introduction

Specialization was once thought to be the rule in pollination ecology. The notion that most plants and their pollinators coevolved in a tight mutualism was the basis for Faegri and van der Pijl's (1979) pollination syndromes. For instance, the "hummingbird pollination syndrome" described flowers pollinated by hummingbirds as always red, tubular, and curved to a degree that matched the birds' bills.

We now know that obligate mutualisms between plants and pollinators are uncommon (Waser et al. 1996). While there are many examples of plants that rely on one pollinator, or pollinators that visit only one plant, these relationships are typically one-sided (Jordano 1987). For example, the tropical bellflower, *Centropogon nigricans*, is only visited by the tube-lipped nectar bat (*Anoura fistulata*), but the bat visits other plant species with tubular flowers (Muchhala 2006). Similarly, the desert miner bee, *Perdita texana,* only visits prickly pear cacti (*Opuntia*) for pollen, but flowers of these cacti are pollinated by many bee species (Barrows et al. 1976).

The sunflower genus (*Helianthus*) is another example of plants that are pollinated by many species. However, several bee genera include "sunflower bees" which primarily collect pollen from sunflowers. Among these are *Andrena*, *Melissodes*, and *Svastra* (Parker 1981, Parker et al. 1981, Bouseman 1982, Greenleaf and Kremen 2006). However, the extent to which these genera rely on sunflower pollen has not been investigated for all species, or throughout their geographical ranges.

The goal of this study was to determine the extent to which bees in the genus *Svastra* specialize on sunflower pollen in the southeastern United States. The author has not observed these bees on flowers other than *Helianthus* in the study area, and predicted that they are sunflower specialists. The *a priori* hypothesis was that more than 50% of *Svastra* individuals collected would be carrying more than 50% of their pollen loads from sunflowers.

Methods and Results

Foraging *Svastra* females were captured on sunflowers at the University of Georgia's Durham Horticulture Farm in Watkinsville, GA, USA (33.89°, -83.42°), between 0900 and 1100 on July 13 and 18, 2011. *Svastra* were not detected on other flower genera during 2011, in spite of weekly searches of all available flowering patches in March- October as part of another study (*unpubl. data*). Specimens were kept on ice until dead and genus identification was verified using Michener (2007) and specimens in the Georgia Museum of Natural History. Specimens were pinned and stored in a standard cardboard collection box until processed.

To determine the percentage of sunflower pollen each bee was carrying, the left hind leg was removed at the trochanter from each specimen. Legs were vortexed in 4mL tap water for 30 s to release scopal pollen, then rinsed with an additional 1mL tap water to remove any remaining loose pollen. A glass pipette was used to dispense 1µL of pollen solution into each of two haemacytometer counting chambers (Improved Neubauer Bright Line/ Dark Line). The number of sunflower pollen grains and the number of total pollen grains were counted in the center 25 squares of both chambers (a volume equal to 0.25mm^3). Sunflower pollen is easily identifiable due to its uniform size and "spiked ball" appearance. The average number of sunflower pollen grains between

the two chambers was used to calculate the average percentage of sunflower pollen grains carried by each bee.

A total of 51 bees were collected, 34 of which were carrying pollen. Of the bees carrying pollen, 33 (86%) carried 100% sunflower pollen, while only one bee (14%) carried less than 100% sunflower pollen.

Discussion

More than 50% of *Svastra* individuals collected were carrying more than 50% sunflower pollen. The fact that only one bee carried less than 100% sunflower pollen suggests that this genus is a sunflower specialist in the study area. The degree to which these data can be generalized is undetermined, due to the small sample size in this study. However, this is the first evidence suggesting that one or more *Svastra* species are sunflower oligoleges in the southeastern United States. This genus has also been found visiting sunflowers in Arkansas (Posey, Katayama, and Burleigh 1986), but the degree of specialization was not documented in that study. *Svastra* species have also been found visiting legumes in Alabama (Cane 1995) and Oklahoma (Thorp and Estes 1975), and an invasive thistle in Oregon (McIver, Thorp, and Erickson 2009). The diversity of foraging preferences within this genus certainly warrants further study.

Another topic for future research is the potential for *Svastra* species as candidates for commercial sunflower pollination. The specialist behavior of the genus in this study supports earlier evidence that these bees are important pollinators for oilseed sunflower (Posey, Katayama, and Burleigh 1986). Although honey bees (*Apis mellifera*) are most commonly managed for sunflower pollination in the U.S., evidence suggests they are less effective than native bees at facilitating seed set (Parker 1981). Parker (1981) also found that visitation by native sunflower oligoleges caused higher seed set

than any other bee group. The fact that *Svastra* showed high sunflower pollen fidelity in this study warrants additional research.

Recent losses in honey bee colonies have sparked interest in the use of native bees for crop pollination. Where honey bees are still used as crop pollinators, the presence of native bees has been found to increase the effectiveness of honey bees as pollinators (Greenleaf and Kremen 2006). Where native bees are protected from pesticides, and provided season-long forage and nesting sites, they can provide all necessary crop pollination, making honey bees unnecessary (Kremen, Williams, and Thorp 2002; Winfree et al. 2007). Bees in the genus *Svastra* show great potential as commercial sunflower pollinators in the southeast, but additional research is needed to understand their basic ecology and manageability.

CHAPTER 2

BUMBLE BEE PHENOLOGY IN THE SOUTHEASTERN USA

Introduction

Bumble bees (genus *Bombus*) are important pollinators in both natural and agricultural ecosystems. These bees are generalist foragers, providing pollination services to a variety of plant families, including Fabaceae, Lamiaceae, Rosaceae, Ericaceae, and others. *Bombus* is one of only a few bee genera capable of pollinating solanaceous plants, and for this reason bumble bees are essential for production of greenhouse tomatoes and peppers (Free 1993, Meisels and Chaisson 1997).

In addition to tomatoes and peppers, there are many other crops for which bumble bees are more effective and/or efficient pollinators than managed honey bees (*Apis mellifera*), including cranberry (MacKenzie 1994), cucumber and watermelon (Stanghellini et al. 1998, Stanghellini et al. 2002). Bumble bees show promise as pollinators of apple (Goodell and Thomson 1997), blueberry (Stubbs and Drummond 1997), red clover and alfalfa (Holm 1966), and raspberry (Willmer et al. 1994). Bumble bees are also important for urban agriculture, providing pollination for home and community gardens that supply food to a growing human population (Matteson and Langellotto 2009).

In spite of their ecological and agricultural importance, there is still much to be learned about bumble bee life history. For many species, information is lacking on typical colony size, nesting behaviors, foraging range, and seasonal phenology. Mounting evidence suggests that bumble bees are declining globally (Colla and Packer 2008,

Goulson et al. 2008, Grixti et al. 2009, Cameron et al. 2011, Kosior et al. 2007), and discovery of their basic life history is necessary for their effective conservation and management.

As mentioned, phenology is an important aspect of bumble bee life history. Phenology is the study of seasonal activity patterns, including abundance, resource use, and colony size. Bumble bee phenology has broad implications for management and conservation because it determines when a species is available to interact with other organisms in its environment. Such interactions include the free pollination services that bumble bees provide to plants that bloom during their active season.

The life cycle of bumble bee colonies has been known for hundreds of years. Bumble bees are social, like honey bees, and a colony is initiated by a mated queen. In contrast to honey bees, the queen bumble bee forages for herself and her developing brood until her first workers emerge. These workers then assume foraging and nest maintenance duties, and the queen focuses on laying eggs and incubating brood. Also in contrast to honey bees, the queen bumble bee is able to increase her body temperature and transfer this heat to her brood, speeding their development (Heinrich 1979). Queens typically produce workers until the end of their active season, at which time they produce males and young queens. These new queens mate, then hibernate through the winter, the only survivors of their natal colony. The next spring, mated queens emerge from their hibernacula to found new colonies, and the cycle is repeated.

While we know the basic bumble bee life cycle, the details of colony phenology are unknown for most species. The majority of research on *Bombus* phenology is from Europe (Goulson 2010), but a few studies have investigated activity patterns in North America. For instance, Hobbes (1967) and Colla and Dumesh (2010) studied the ecology of several bumble bee species in Canada, and de la Hoz (2006) investigated phenology of *Bombus sonorus* in Mexico. Only recently has *Bombus* phenology been

recorded in the USA, in a study of several species in Colorado (Pyke et al. 2011). Reports of phenology for most species found in the USA are based on decades-old information from bees collected in Canada (i.e. Hobbes 1967), and do not take into account the climatic variation within the continental United States. This could be especially important for species, like *B. impatiens*, with large geographic ranges, because their phenology could differ by region and temperature.

The southeastern USA is one region that has received little attention from bumble bee researchers. This area is characterized by mild winters and hot, humid summers, making it an ecologically interesting climate. The southeastern USA is included in the geographical ranges of many *Bombus* species, (Kearns and Thomson 2001), but the presence of these species has not been recently verified. Nor has the phenology of bumble bees in the Southeast been recently compared to that of bees in Canada.

The primary goal of this study was to investigate bumble bee natural history in the southeastern USA, and provide a baseline for future investigations. Data were collected on *Bombus* species presence, and their phenology and floral resource preferences. The author predicted that species' phenology in the study area would be shifted earlier in the season, compared to Canadian reports, and that published range maps might be in need of revision.

Methods

Surveys were conducted weekly from Mar 18- Oct 15, 2010, and Mar 29- Sep 29, 2011 in the piedmont of Georgia, USA. Four sites were used during this study: the Durham Horticulture Farm (HF) in Watkinsville (2010 and 2011), Spring Valley EcoFarms (SV) in Athens (2010), Woodland Gardens (WG) in Athens (2010), and Roots Farm (RF) in Winterville (2011). Each site was surveyed at least twice on all survey

days, in both years. Surveys were conducted between sunrise and sunset in 2010, and between 0900 and 1400 in 2011. Sites were surveyed in random order on all days to minimize the effects of bees' diel patterns on seasonal phenology data.

Early in the season, the author surveyed the largest flowering patch at a site to maximize the likelihood of capturing queens when the number of bees flying was expected to be low. Once workers appeared, a 4-bee minimum was applied for conducting surveys. A site was considered to have insufficient bloom, and no survey was conducted, if no flowering patch could be located with at least 4 bumble bees. This rule was applied to avoid conducting surveys at a site while it offered no floral rewards. Once workers were observed, all sites were explored for bumble bee activity prior to starting the first survey on each day. If more than one flowering patch contained 4 or more active bumble bees, the largest patch was used in all surveys at that site for that day.

Surveys were conducted in 10 min search intervals, in which the author searched for bumble bees by walking around and/or through the selected flowering patch in a haphazard manner. A standard survey protocol was not developed because, (1) few patches were in bloom for more than one survey, (2) it was not possible to anticipate the time at which patches would come into bloom, and (3) it was difficult to predict which flowers would be visited by bumble bees on a given day. There were many days in which bees were observed in one flowering patch at the exclusion of another that appeared equally rewarding.

The author attempted to capture all bumble bees seen during a survey, and stored them in plastic screw-top containers (Container Packaging Supply company, clear PET single-wall jars, 1oz and 2oz) for later identification. Bees were either captured by netting (Bioquip white 12" aerial net), or by placing a container over their body and gently pushing them into it with the lid. When outside temperatures were above 29.4^{o}C, bees

were kept in a cooler with an ice pack during surveys to minimize overheating. The plant species on which each bee was captured was identified to genus, and whether or not females were carrying pollen in their corbiculae was recorded.

Weather conditions were recorded either at the beginning (2010), or the end (2011) of each survey. Air temperature, relative humidity, and heat index were measured with a Kestrel 4500 weather meter, approximately 1m above the ground, in the shade, 3-4m from the flowering patch surveyed. Measurements were recorded near, rather than from within, flowering patches to minimize the effects of plant transpiration.

Upon survey completion, all captured bees were immediately identified to sex, caste, and species by observation of color patterns, and relative size, body proportions, and pile length. This is a common method of field identification, and was sufficient for distinguishing 3 of the species captured (*Bombus impatiens, B. griseocollis,* and *B. bimaculatus*). Three other species were identified *(B. auricomus, B. fraternus,* and *B. pensylvanicus,* denoted hereafter as *Bombus* a-f-p) by comparison with museum specimens, but were too difficult to distinguish in the field. Genetic identification was beyond the scope of this study, so the phenology of these species are grouped and discussed together.

Bumble bees were released immediately after identification, and surveys were separated by 20-min intervals, starting with the release of the last bee captured in the previous survey. This interval was intended to minimize the effects of capture on subsequent foraging activity. It is possible that bees were recaptured, however, this was considered to have little effect on the results, since this study is a qualitative measure of bumble bee phenology and abundances are reported as averages.

The *Bombus* collection at the Georgia Museum of Natural History was also examined for phenology patterns. While museum collections do not indicate sampling effort, they can be valuable for identifying shifts in species phenology, as in Cameron et

al. (2011) and Grixti et al. (2009). Specimens were included in this study if captured within an 80.5 km radius of Athens, GA USA.

The average number of bumble bees captured per survey was used in generating phenology graphs for each species by site. Caste phenology graphs were generated for each species using the average number of bees of each caste captured on a given day, across all sites. Graphical representation of phenology patterns is a common method of reporting these data across animal taxa, as seen in Browne and Aebischer (2003), Colla and Dumesh (2010), Danforth (1999), de la Hoz (2006), Pyke et al. 2011, Scheunert et al. (2010), and Stiles (1975).

Results

Environmental Factors

Temperatures during 2010 surveys ranged from 5.4^{o} C - 38.4^{o}C, with a maximum heat index of 46.7 ^{o} C, in August. Humidity ranged from 25% - 91%, and was typically highest during morning and evening surveys. In 2011, temperatures during surveys ranged from 9.9^{o}C – 30.2^{o}C, with a maximum heat index of 29.8^{o}C in May. Relative humidity ranged from 33.8% - 86.7%. There was no apparent correlation between temperature and bee activity in either year, but few bees were captured when the heat index was above 43.3^{o}C in 2010.

Plant Interactions

Plant genera visited by each bumble bee species is shown in Table 2.1. In both years, bees visited many plant families, including Fabaceae, Solanaceae, Cucurbitaceae, Lamiaceae, and Rosaceae. The non-native herb deadnettle (*Lamium purpureum*) and commercial blueberry (*Vaccinium* sp.) were commonly visited by queens in March and April, 2010. In 2011, blueberry and non-native crimson clover

(*Trifolium incarnatum*), were most commonly visited in the same months. Non-native white clover (*Trifolium repens*) that was sown as ground cover was commonly visited when no other flowering patches were available. The non-native lavender chaste-tree (*Vitex agnus castus*) and native giant hyssop (*Agastache foeniculum*) were both frequently visited in mid-summer. Bees were commonly captured on more than one plant species during a single survey, including crops and "weedy" species. Goldenrod (*Solidago* sp.) was an important forage source in fall of 2010, but no bees were captured on it in 2011. Bumble bees were rarely observed visiting crops under plastic hoop-houses, even though they were not restricted from entering.

Bumble bees appeared to be collecting pollen only from a subset of blooming species. The author frequently observed workers removing and discarding squash pollen (*Cucurbita* sp.) after becoming covered with it while drinking nectar. Table 2.2 shows the percentage of bees with a pollen load for plants from which more than 50% of captured bees were carrying pollen. Although *Vitex* and *Lamium* were commonly visited, only 17.8% and 20%, respectively, of bees captured on these plants were carrying pollen. Eggplant and nightshade (both *Solanum*) had the highest percentage of captured bees carrying pollen.

Year Effects

Species phenologies were different across years, and are graphed separately (Figs. 2.1 – 2.8). *Bombus* males were still being captured during the last survey in October in 2010, but in 2011 bumble bees could not be found after the month of June. *Bombus impatiens* was the most abundant species in both years (Figs. 2.5, 2.6), followed by *B. griseocollis* (Figs. 2.3, 2.4). *Bombus bimaculatus* and the *Bombus* a-f-p group were found at similarly low abundance in both years (Figs. 2.1, 2.2, 2.7, 2.8).

Average abundance was higher in 2010 for all but one species. The highest average number of individuals found per survey for *B. bimaculatus* was 6.5 in 2010, compared to less than 1 in 2011. There was an average peak of 9 bees in the *Bombus* a-f-p group in 2010, but fewer than 1 individual in 2011. *Bombus impatiens* averages peaked around 30 in 2010, but only reached 20 in 2011. The average peak abundance of *Bombus griseocollis* was lower in 2010 than in 2011 by about 2 bees per survey.

Site Effects

An overall bimodal phenology pattern was observed for all species, across sites, in 2010 (Figs. 2.1, 2.3, 2.5, 2.7). However, species' phenology was often different at SV, compared to other sites. For example, all species except *B. impatiens* were found earlier in the season and showed longer active seasons at SV. Also, there were several days in which the abundance of a species increased or remained the same as the previous week at SV, while it declined at the other sites.

Phenology (2010)

Bombus bimaculatus had the earliest abundance peak of all species, in April (Fig. 2.1). This species also had the shortest active season, with worker numbers peaking in early June, and activity ending after the third week of June. *Bombus griseocollis* showed an initial abundance peak in April, followed by a larger peak that lasted from early June into early July. This species was not observed after mid-August (Fig. 2.3). *Bombus impatiens* had the longest active season of all species, with an initial peak in mid-May; it remained abundant at some sites from June into October (Fig. 2.5). *Bombus impatiens* workers also appeared to vary more in size than those of other species. The combined phenology of the *Bombus* a-f-p group showed two early peaks;

one in April, and another in late May. A second peak in abundance was observed in July for these species (Fig. 2.7).

Caste phenology was graphed for 2010 only, because of a lack of sufficient data from 2011. *Bombus bimaculatus q*ueen abundance peaked in April, worker abundance in May, and male abundance in June. A few young queens of this species were captured in July (Fig. 2.9). *Bombus griseocollis* queen abundance peaked three times; in April, May, and July. Worker and male abundance overlapped for *B. griseocollis*, from May into June (Fig. 2.10). Very few queens of *Bombus impatiens* were captured, but workers of this species peaked in June and again in August, and male abundance was highest in October (Fig. 2.11).

Museum Specimens

Phenology from field captures of all but one species were corroborated by the museum collection (Table 2.3). Two museum specimens of *B. bimaculatus* were collected in September and October in different years; this is 3 months after the end of the active season of this species in 2010. In addition, the museum collection contained two specimens of *B. affinis*, but this species was not captured in either year of the study.

Discussion

Year Effects

The most striking result of this study was the difference in bumble bee abundance between years, for which there are two likely explanations. This could reflect an actual decline in bumble bee populations in the area, or merely a decline in the number of bees visiting the study sites.

First, an actual bumble bee decline in 2011 might result from a paucity of resources the previous year, leading to low numbers of founding queens in 2011. This

could have caused the number of active colonies to be low, and the number of bees flying on most days to have been below the established threshold. The lack of phenology data prior to this study makes it impossible to determine whether these results are normal for the species observed.

Another potential cause of a real decline is a mass die-off during 2011, possibly resulting from pesticides or disease. The HF and RF sites used in 2011 are approximately 22.5 km apart, and managed differently. Pesticides were used weekly in both years at the HF, on blueberry, peach, walnut, and other crops. The RF, though not certified organic, attempted to minimize pesticide use as part of their sustainability goals, and made few chemical applications during the year. Considering that the phenology for all bumble bee species is similar at both study sites during 2011, a pesticide kill seems unlikely. The possibility of a sudden disease outbreak among bumble bees in the area warrants further investigation, but was beyond the scope of this study.

Second, the lower bumble bee abundance in 2011 could be site-specific, and the result of poor floral resources at the locations used. The foraging range of bumble bees in North America has not been investigated, but several studies from Europe show that *Bombus* workers might travel considerable distances while foraging (Knight et al. 2005, Walther-Hellwig and Frankl 2000, Osborne et al. 1999). Hagen, Wikelski, and Kissling (2011) used radio tracking to measure foraging range in *B. terrestris*, *B. hortorum*, and *B. ruderatus*. The average maximum flight distance was 991m, with the greatest distance recorded as more than 2,500m. These studies suggest there could be significant species differences in foraging range, and that bumble bees do not necessarily forage near their nests. More research into foraging distance for bumble bees in the US is warranted. While this study did not investigate floral resources outside the study sites, the presence of flowering resources nearby is plausible, considering their rural locations. Future studies of bumble bee abundance and occurrence could be

inaccurate if not measured at a regional scale, using sites with a diversity of floral resources.

Plant Interactions

The variety of plants visited by bumble bees in 2010 supports our knowledge of them as generalists. However, bees appeared to be collecting pollen from only some plant species. For instance, queens were often captured on deadnettle, but fewer than 50% were carrying pollen. On the other hand, more than 79% of bees captured on clovers, 81% on eggplant, and 100% on nightshade, were carrying pollen. This suggests that bumble bees prefer some pollens over others, which could have implications for their conservation. Further study on pollen preferences of bumble bees in the US would be informative.

Site Effects

Another interesting result from this study was that bumble bee abundance and active season were not the same among sites. Active season was longer and abundance was greater for all but one species at SV in 2010. This is best explained by the presence of early and season-long forage resources. For instance, SV allowed "weedy" species like deadnettle, and ground covers like vetch and white clover, to bloom and go to seed. Deadnettle was the first plant on which bumble bees were captured during the year, and SV was the only site at which it was present in numbers and allowed to bloom. At other times, there was an abundance of vetch and clover blooming at SV, providing pollen and nectar between crop blooms. Vetch was scarce, and white clover was frequently mown, at both other sites, and there were also more periods of low resource availability at these sites. These results support the literature emphasizing the importance of season-long forage in maintaining bumble bee populations, and that

plants typically considered “weedy” can be important resources (i.e. Goulson, Lye, and Darville 2008; Goulson 2010).

Phenology

Species phenology generally followed a pattern that is consistent with our knowledge of the bumble bee life cycle. Queens were always first to be captured, followed by workers, and then males. It is interesting to note that very few queens were captured near the end of the active season for any species. It is possible that few queens were produced, or that they were dispersed over such a large area that the likelihood of capturing them was low.

One particular challenge in exploring colony phenology in the US is the difficulty in finding wild nests. Few reports exist of wild nest locations in the US, and it is presumed that bumble bees commonly nest underground, in wooded habitats. Bumble bees in the US colonize artificial nest boxes at a low percentage (Robbin Thorp, *personal communication*), and they are difficult to domesticate. Only *B. occidentalis* in the West and *B. impatiens* in the East have been domesticated with any success. More research is needed to elucidate species preferences for nest sites and their characteristics.

To the author’s knowledge, this study represents the first record of *B. bimaculatus* phenology in the United States. Several interesting differences exist between the phenology of this species in Georgia and conspecifics in Canada (Colla and Dumesh 2010). First, this species was captured more than a month earlier in Georgia. Second, the active season for *B. bimaculatus* was 2 months shorter in Georgia. Third, caste abundance peaks in Georgia were spread over 3 months, compared to 1 month in Canada. For instance, queen abundance in Georgia peaked a month before that of

workers, which was also a month before that of males. In the Canadian study, all castes peaked between June and July.

Similar differences in caste phenology were found for *B. griseocollis.* Canadian bees showed all caste peaks in July and August, while conspecifics in Georgia showed not only a greater temporal spread, but more than one peak per caste. The active season for *B. griseocollis* also ended earlier in Georgia than in Canada.

Bombus impatiens phenology in Georgia also differed from that in Canada, but in the opposite manner as that of *B. bimaculatus* and *B. griseocollis*. *Bombus impatiens* had a longer active season in Georgia than in Canada, by more than a month. Worker abundance in Canada peaked in July, and that of males in September, and all castes were declining at the time of the last record in October. In Georgia, worker abundance peaked three times, and male abundance was increasing at the study's conclusion in October. Both studies suggest that queen abundance is low for this species, which supports previous records of *B. impatiens* populations as consisting of a few, large colonies.

The phenological differences between bumble bees in Canada and Georgia are possibly explained by temperature. *Bombus bimaculatus* and *B. griseocollis* in Georgia ended their active seasons two months earlier than conspecifics in Canada. This suggests that these species might have evolved an earlier active season to avoid the hottest time of the year in the South. *Bombus impatiens*, on the other hand, might be more heat-adapted and able to tolerate the temperatures during the hottest months in the southeastern USA. A study on greenhouse pepper pollination using *B. terrestris* showed that bee activity decreased at temperatures above 32.7^{o}C (Kwon and Saeed 2003). The results of this and the present study suggest that temperature could be important in regulating bumble bee foraging activity.

The phenology of the *Bombus* a-f-p group could not be separated in this study. However, their combined phenology suggests that they are all uncommon in the area, and that their abundance peaks in late summer. Of these species, only *B. auricomus* and *B. pensylvanicus* were included in Colla and Dumesh's study (2010), but their results show these species as being most abundant late in the season. Further research is needed to separate the phenology of these species in the Southeast, and to determine whether their populations are chronically low or declining.

Species Ranges

Fourteen *Bombus* species are documented as having ranges that include the southeastern USA (Kearns and Thomson 2001). Only 8 of these were captured, or included as museum specimens, in this study. *Bombus affinis*, *B. terricola*, *B. fervidus*, *B. perplexus*, *B. ternarius*, *B. vagans*, and *Psithyrus citrinus* are documented by Kearns and Thomson (2001) as being present in the Southeast, but this author is confident that they were not present at any study site in either year. This suggests that these species are either not present in the region, or are uncommon. Kearns and Thomson's (2001) range maps are based on decades-old reports (i.e. Hobbes 1967, Plath 1934, Milliron 1973), and these results suggest that a re-evaluation of species ranges is in order.

Conclusions

This study is the first to document bumble bee phenology in the southeastern USA, and the first record of *Bombus bimaculatus* phenology South of Canada. Caution is needed when generalizing these results across the region, but this study highlights several areas for further investigation. First, there is clear evidence of a need for long-term study of bumble bee phenology in the USA to capture interannual and site variation. There appear to be interesting phenological differences among species within

a region, within species across their geographic ranges, and across years. Second, preferred nectar and pollen resources must be investigated for all bumble bee species in the US if we are to understand their life history and plan for their conservation. Third, this study further demonstrates the importance of season-long forage for maintaining bumble bee populations, and this information must be disseminated to growers and landowners to encourage them to maintain bee forage on their properties.

Tables and Figures

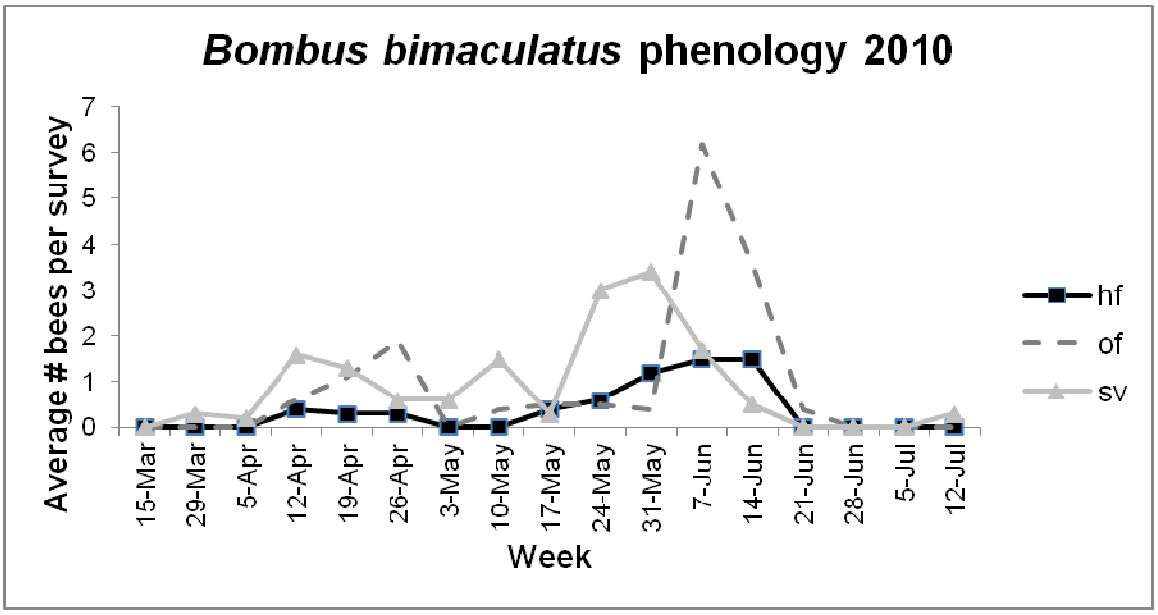


Figure 2.1. Seasonal phenology of *Bombus bimaculatus* in 2010 at three sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; OF= Woodland Gardens in Athens, GA; and SV= Spring Valley EcoFarms in Athens, GA.

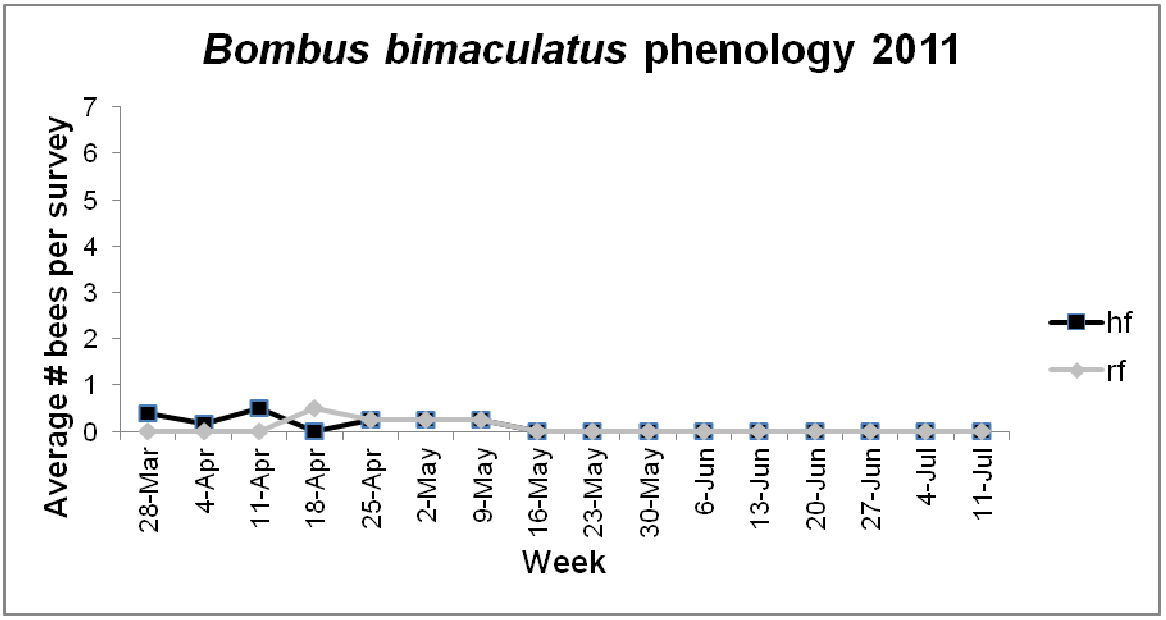


Figure 2.2. Seasonal phenology of *Bombus bimaculatus* in 2011 at two sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; RF= Roots Farm in Winterville, GA.

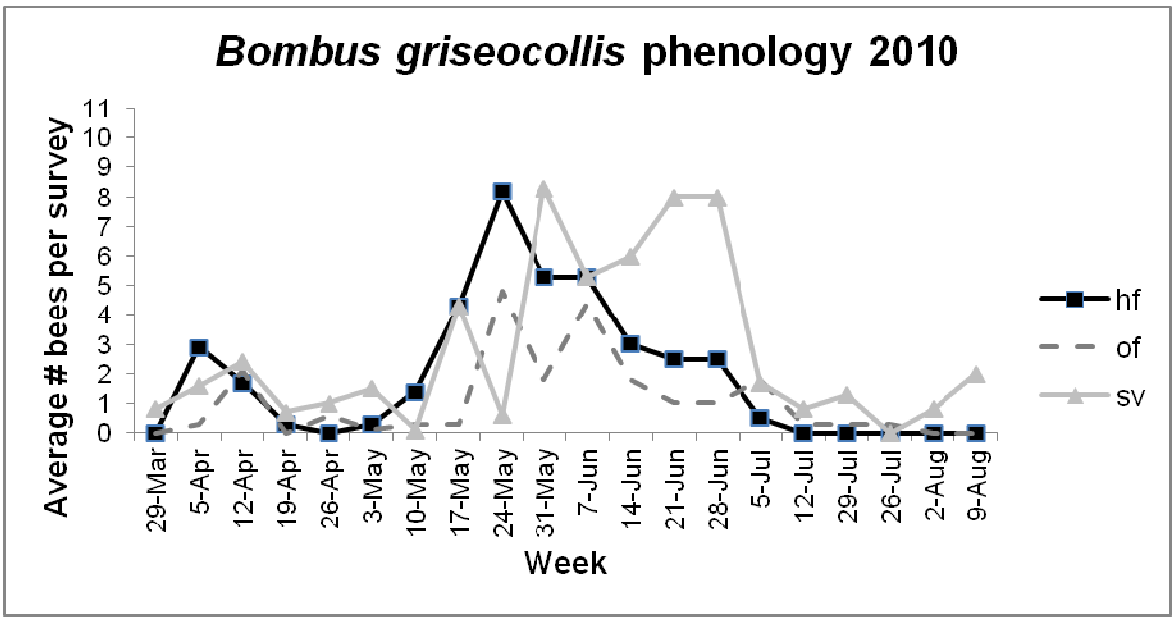


Figure 2.3. Seasonal phenology of *Bombus griseocollis* in 2010 at three sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; OF= Woodland Gardens in Athens, GA; and SV= Spring Valley EcoFarms in Athens, GA.

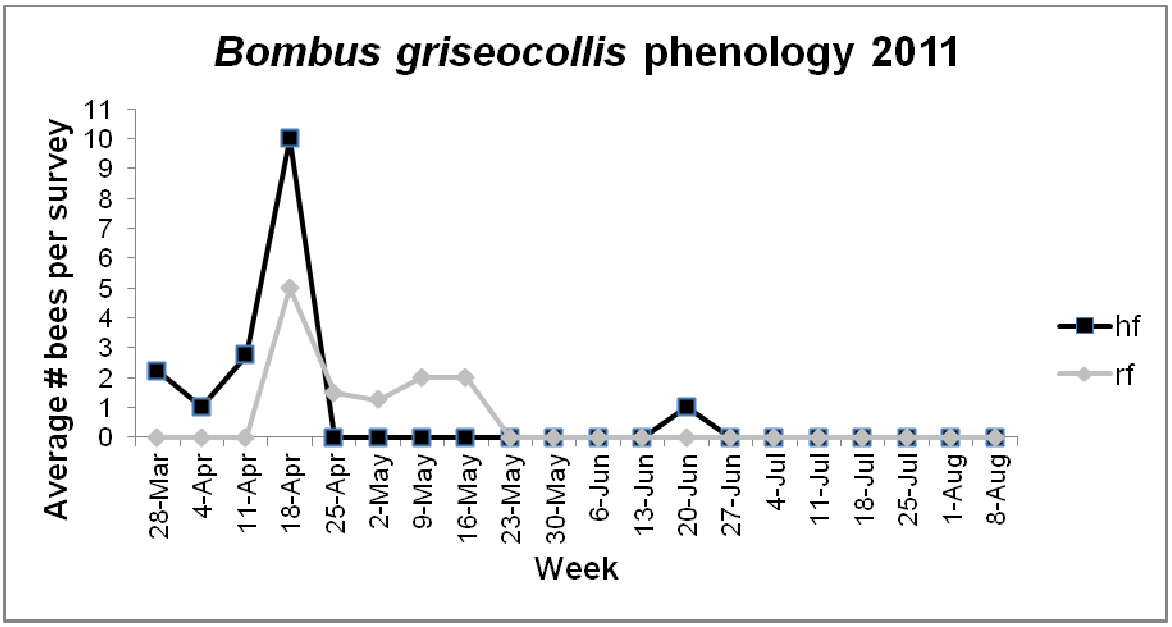


Figure 2.4. Seasonal phenology of *Bombus griseocollis* in 2011 at two sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; RF= Roots Farm in Winterville, GA.

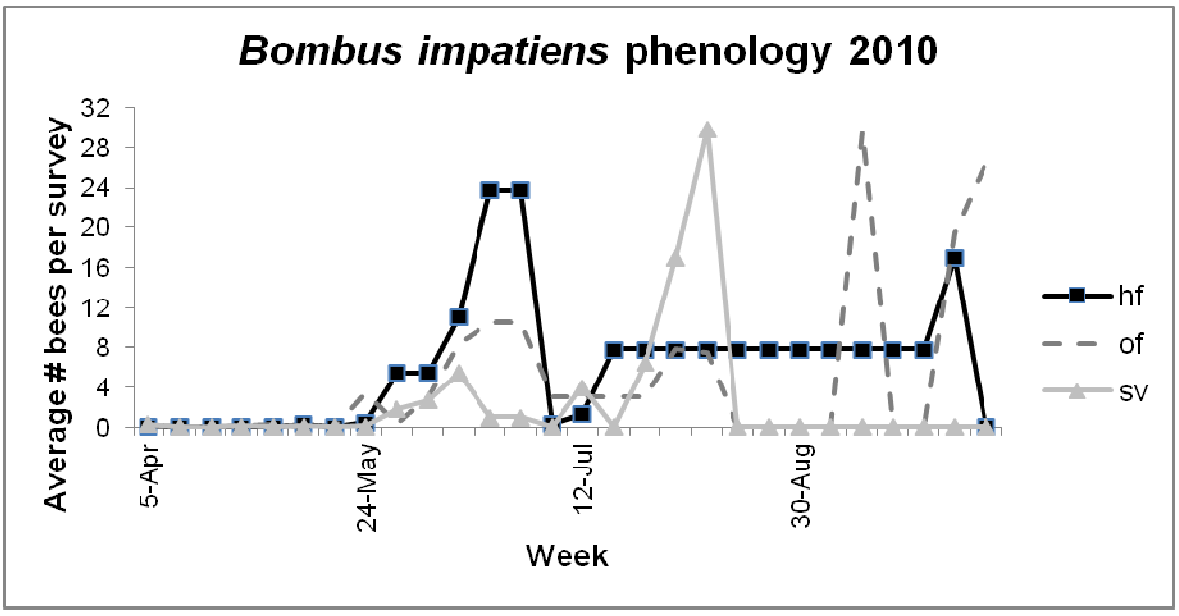


Figure 2.5. Seasonal phenology of *Bombus impatiens* in 2010 at three sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; OF= Woodland Gardens in Athens, GA; and SV= Spring Valley EcoFarms in Athens, GA.

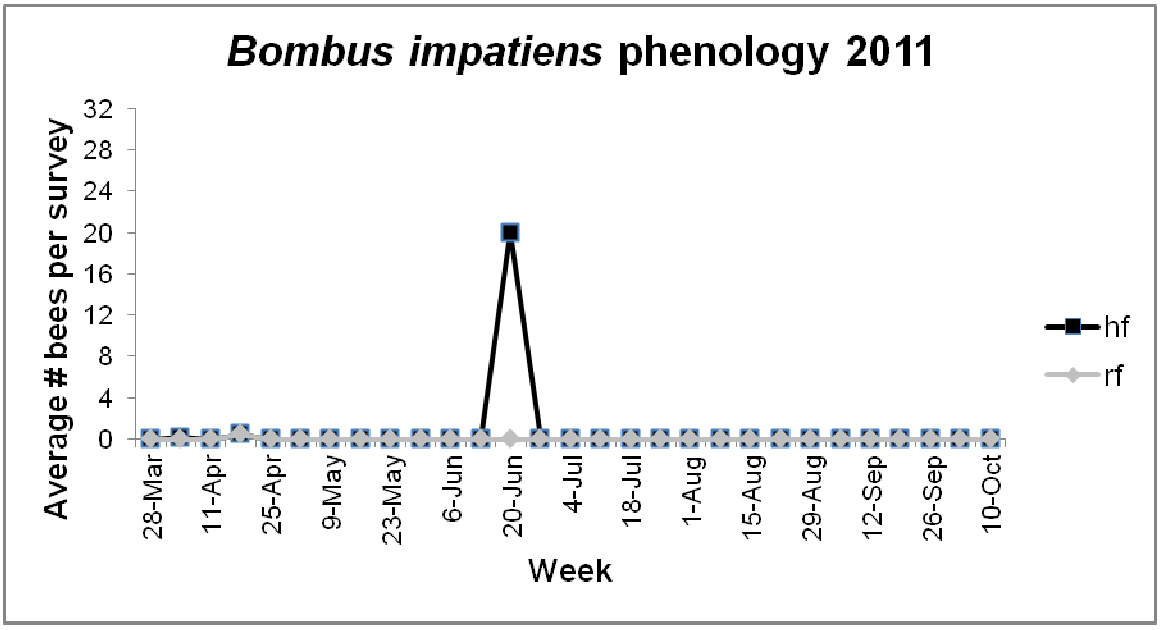


Figure 2.6. Seasonal phenology of *Bombus impatiens* in 2011 at two sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; RF= Roots Farm in Winterville, GA.

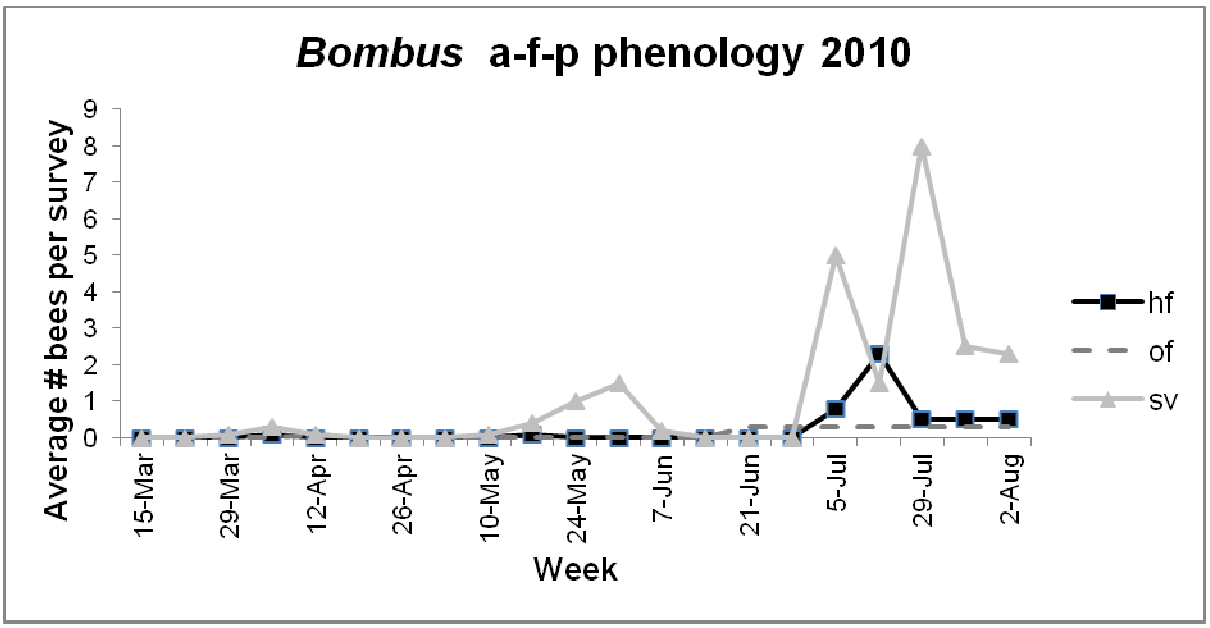


Figure 2.7. Combined seasonal phenology of *Bombus auricomus* (a), *B. fraternus* (f), and *B. pensylvanicus* (p) in 2010 at three sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; OF= Woodland Gardens in Athens, GA; and SV= Spring Valley EcoFarms in Athens, GA.

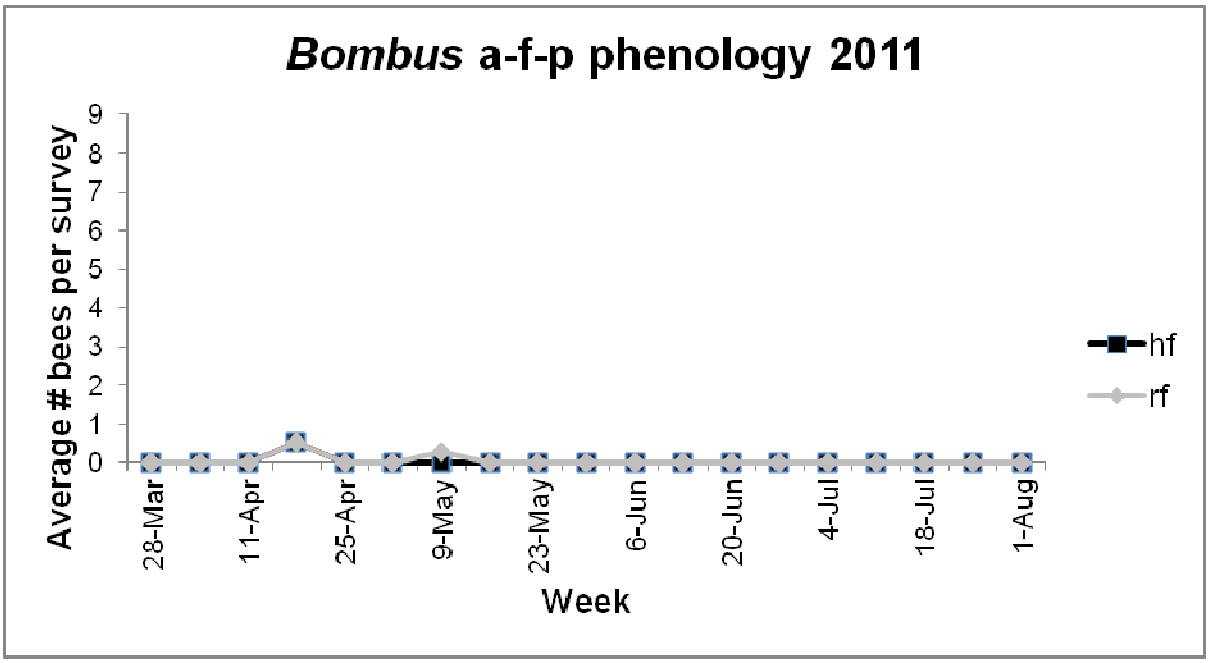


Figure 2.8. Combined seasonal phenology of *Bombus auricomus* (a), *B. fraternus* (f), and *B. pensylvanicus* (p) in 2011 at two sites in Georgia USA. HF= Durham Horticulture Farm in Watkinsville, GA; RF= Roots Farm in Winterville, GA.

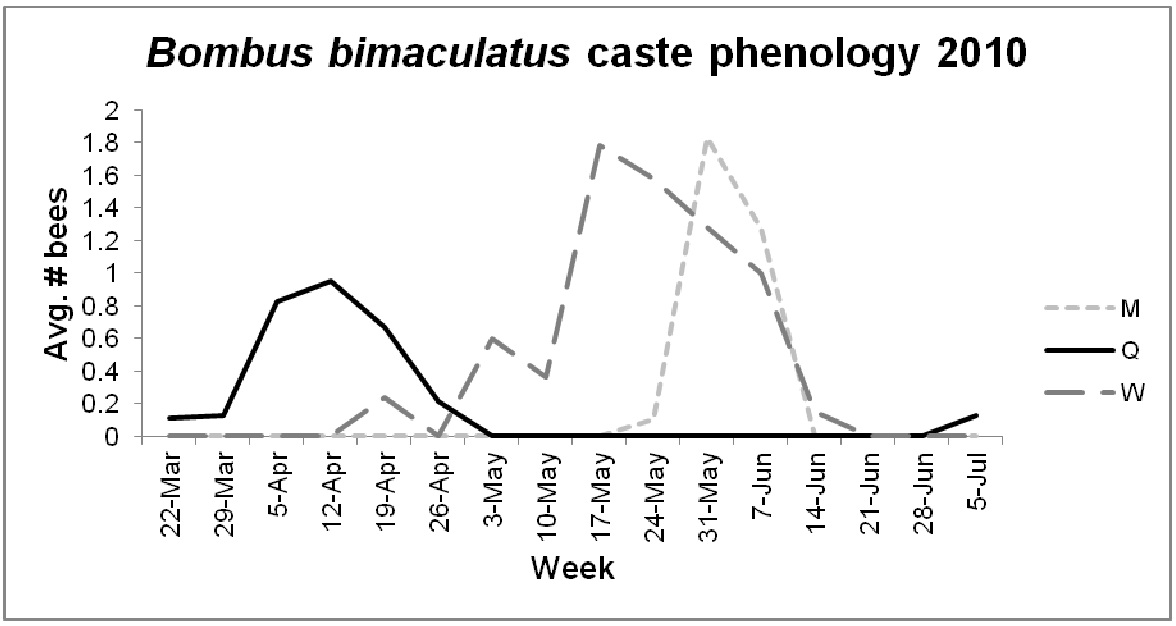


Figure 2.9. Caste phenology for *Bombus bimaculatus* in 2010. Averages are for all bees captured across three sites near Athens, GA, USA. M= males, Q= queens, W= workers.

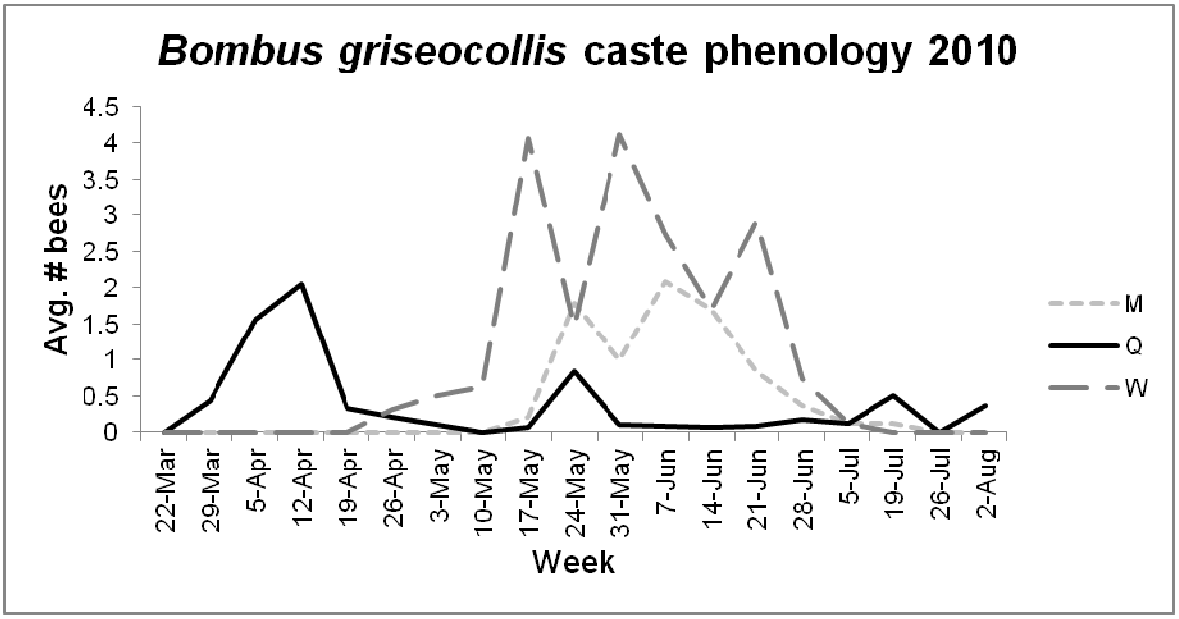


Figure 2.10. Caste phenology for *Bombus griseocollis* in 2010. Averages are for all bees captured across three sites near Athens, GA, USA. M= males, Q= queens, W= workers.

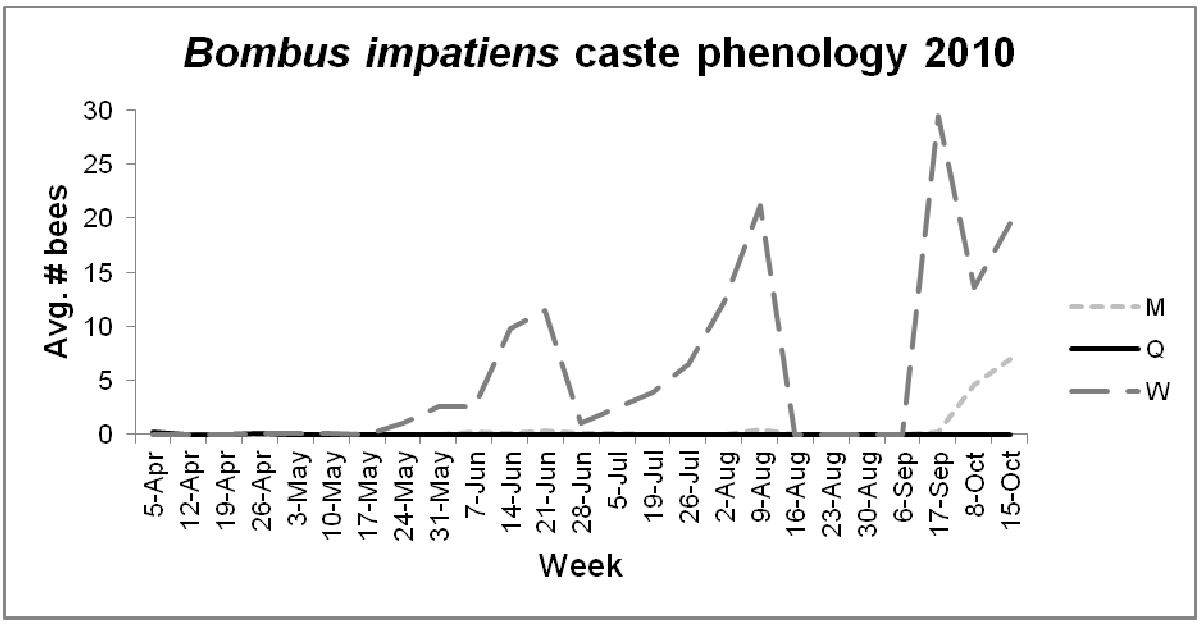


Figure 2.11. Caste phenology for *Bombus impatiens* in 2010. Averages are for all bees captured across three sites near Athens, GA, USA. M= males, Q= queens, W= workers.

Table 2.1. Plant genera visited by bumble bees near Athens, GA, USA, in 2010. An “X” indicates that the genus was visited. An asterisk indicates genera non-native in the study area. Months below genus names denote bloom period.

Bombus	**Lamium*	*Vaccinium*	**Pisum*	**Trifolium*	*Vicia*	*Rubus*	**Lupinus*	*Plantago*	*Cirsium*	**Cucurbita*	*Solanum*	**Vitex*	*Monarda*	*Agastache*	*Helianthus*	*Echinacea*	**Cucumis*	**Citrullus*	*Oenothera*	**Ocimum*	*Aster*	*Solidago*
	Mar-Apr	Apr	May	Apr-Jul	Apr-May	May	May	May-Jul	May	May-Jul	May-Jul	Jun-Jul	Jun	Jun-Jul	Jun-Aug	Jun-Jul	Jul	Jul	Jul			
bimaculatus	X	X	X	X	X	X		X	X	X	X	X	X	X								
griseocollis	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X				
impatiens		X		X	X	X		X		X	X	X		X	X		X	X	X	X	X	X
a-f-p	X	X	X	X	X				X	X	X	X	X	X	X	X	X	X				

Table 2.2. Plant genera on which bumble bees (*Bombus*) were captured in 2010 near Athens, GA, USA, showing the percentage of captured bees carrying pollen.

plant	total bee captures	%w/pollen
Aster	39	51.3
Oenothera	31	64.5
Vaccinium	133	64.7
Vicia	82	70.7
Ocimum	186	76.3
Trifolium	230	79.1
eggplant (*Solanum*)	87	81.6
nightshade (*Solanum*)	18	100.0

Table 2.3. Bumble bee specimens from the Georgia Museum of Natural History, collected within an 80km radius of Athens, GA, USA.

Bombus	oldest	youngest	month range	n
bimaculatus	1931	1971	Mar - Oct	22
griseocollis	1937	1999	May - Oct	6
impatiens	1935	2003	Mar - Nov	148
auricomus	1971	1971	June	1
fraternus	1937	1998	Apr - Oct	4
pensylvanicus	1936	1998	Apr - Nov	83
affinis	1966	1998	May - Jun	2

CHAPTER 3

MAXIMIZING THE USE OF SOCIAL MEDIA FOR OUTREACH PROGRAMS

Introduction

Social media has the potential to connect even small organizations to a global audience. Social media, also known as Web 2.0, is a collection of interactive online platforms, such as blogs (web logs), podcasts, Twitter, YouTube, and Flickr. The social nature of these platforms allows users to share content with each other, contribute their own content, and interact with other content authors. In contrast to Web 1.0 technology, such as online dictionaries and static websites, social media is more informal, more interactive, and puts the power of knowledge creation into the hands of the public.

A brief definition of several social media platforms follows:

- *Blog* (aka blog roll): a display of short articles (called posts) in reverse chronological order. Posts are archived on the site, grouped into categories, and searchable. Posts also typically have a comments section in which readers can leave messages and ask questions.
- *Podcast*: audio broadcast of content that can be downloaded onto mobile devices and stored for later listening.
- *Twitter*: a site on which an organization or individual posts a short message (a “tweet”), usually containing a link to a relevant website or page.
- *YouTube*: video sharing site, owned by Google, that allows anyone to upload and display videos on the internet.

- *Flickr*: photo sharing site, owned by Yahoo!, that allows anyone to upload and display digital photographs on the internet.
- *RSS*: real simple syndication, which allows users to subscribe to a blog and receive posts on their mobile devices, instead of having to access the internet to read them.

Social media is very popular; Technorati was tracking more than 1.2 million blogs on the internet, as of February 21, 2012, and the site reported "explosive growth" in the number of blogs since they started monitoring them in 2004 (http://technorati.com/state-of-the-blogosphere/). As of the same date, there were more than 38 million active Twitter accounts (http://www.whisthis.com/#Twitter%20Accounts). YouTube reported on May 25, 2011, that it had 3 billion video views every day (http://youtube-global.blogspot.com/2011/05/thanks-youtube-community-for-two-big.html), and that number has likely increased since that time. Flickr was reported to have 51 million registered members, and 20.6 million unique visitors in August, 2011 (http://advertising.yahoo.com/article/flickr.html).

The combined popularity and ease of using social media allow organizations to reach and interact with more people than has ever been possible. Use of social media can be especially beneficial for outreach programs, such as those conducted by agricultural extension agencies, libraries, nature centers, and museums. Social media allows these organizations to have a professional online presence, communicate their message, and interact with their audience, without the technical skills that were necessary with Web 1.0 applications. For instance, someone with basic computer skills can set up a free blog and publish content within minutes. Establishing Twitter and YouTube accounts is even easier.

Many types of organizations currently use social media in their outreach efforts. For instance, groups involved in health care use blogs to educate their readers about

research and publications (Sublet et al. 2011), general public health issues (Sapp and Cogdill 2010), and disaster preparedness (Wilson and Yowell 2008). Agricultural extension agencies use blogs to educate about gardening and landscaping (Gillman et al. 2011), turfgrass management (Jones et al. 2011), integrated pest management (DiPietro and Miller 2009), and youth 4-H programs (Ashton et al. 2010). The blog of the Bird Ecology Study Group uses their blog to inform people of bird behavior and localities, soliciting images and content from the public, and occasionally publishing their observations (Wee 2011). Many of these blogs also feature an RSS subscription option.

The websites for many nature centers and natural history museums also have blogs through which they attempt to engage their audience. But, in spite of the popularity and potential of blogs and other social media, few outreach programs utilize the suite of available platforms to their greatest advantage. For instance, a Google search of “nature center” and “blog” returned only 8 nature centers with blogs on their websites (February 13, 2012). Of these, all displayed social sharing buttons (such as Facebook or Twitter), but only half offered an RSS subscription option (Table 3.1). None of these nature centers indicated that they were using other social media. Average post frequency during the months of August, 2011, through January, 2012, for these nature centers ranged from 0 to 6.7 per month, and all blogs allowed public comments.

A similar search for “natural history museum” and “blog” returned only 5 sites, 4 of which displayed social sharing buttons, and 3 of which offered RSS subscription options (Table 3.1) . Only two sites used more than these social media platforms. Four out of the five blogs allowed comments. One site stands out for its use of social media: the website for the Natural History Museum in London has 16 blogs with posts published almost every day among them, RSS subscription options, social buttons for each blog, and a link to their YouTube channel.

Social media can be most effective in outreach programs, both for reaching an audience and attracting visitors, if several platforms are combined and used in a complimentary fashion. This article is an exploration of the use of several social media platforms in the outreach efforts of an individual scientist (the author). Website setup and goals are described, followed by the marketing strategies and social media used to advertise the site and encourage visitor interaction. This is followed by a report of site statistics and visitor interactions. A discussion follows that examines the utility of the social media platforms used, and the overall success of the site's outreach efforts.

Methods

Site Philosophy

The author's primary goal was to educate non-scientists about pollinating animals, such as bees, bats, and moths, and their importance to our everyday lives. The author also wanted the site to be relevant to visitors from anywhere in the world, and to be viewed as a trusted source for information about pollinators and related issues. The site was set up with a blog and several static pages, as described below.

Site Organization

The site was named Pollinators Info, because the author felt that this best represented the goal for the site to be a reliable source of information about pollinators. The domain .info was chosen because pollinators.com and pollinators.org were being used. The site's web address was registered as www.pollinators.info.

Initially, the site contained eight pages:

1. Home- the blog roll
2. Welcome!- a short introduction to the site and its focus

3. Author- information about the author, her education, and goals of providing accessible and accurate information
4. Links- links of interest to pollinator-related sites or resources
5. Agriculture- an introduction to the importance of pollinators to agriculture, and some related links of interest
6. Gardening- an introduction to pollinator gardening and some related links of interest
7. Education- an introduction to teaching with pollinators and some related links of interest
8. Shop Here!- links to pages on Zazzle.com where logo merchandise could be purchased

Two additional pages were added within a few months of the site's launch:

9. Product Reviews- the author's reviews of pollinator-related books, and the camera she uses to photograph pollinators.
10. Subscribe Here!- a description of the free weekly newsletter, benefits of subscribing, and a short subscription form.

Several types of posts were published 1-7 times per week between May 13, 2011 and February 13, 2012. All posts included a relevant image, links to related content, and related resources. For instance "Pollinator Profiles" posts featured a photograph of an animal pollinator and gave detailed information about its life history and the plants it pollinates (Appendix A, #1). "Take Action" posts gave readers ideas for making small changes on their property to benefit pollinators (Appendix A, #2). Interview posts showed a written dialog between the blog author and someone of interest. For instance, the author interviewed Dr. Scott Hoffman Black, the director of the Xerces Society for Invertebrate Conservation, and co-author of the book, Attracting Native Pollinators, via email about the book and its message (Appendix A, #3). Another type of post was

designed to be catchy and relate to almost any viewer. The post, “Victoria’s Secret loves pollinators (even if they don’t realize it)” told the story of cotton pollination and that much of Victoria’s Secret’s products would not be possible without native bees (Appendix A, #4). Other posts highlighted a free pollinator-related resource, like fact sheets, lesson plans, and brochures, and provided a link to a .pdf file of the document (Appendix A, #5).

Intense Debate was used as the comment platform, because it allowed visitors to ask multiple questions on every post, receive responses from the author, and interact with each other. This format also did not require visitors to login or sign up to leave comments. The author responded to all visitor comments within 7 days.

Marketing

Pollinators Info was launched on May 13, 2011, and announcement emails were sent to 266 nature centers, natural history museums, and botanical gardens in the USA. The site was advertised as “your source for pollinator-related information, resources, and community.” Posts could be accessed via the internet or RSS feed. The author developed a logo, using Microsoft PowerPoint (Fig. 3.1), and created merchandise (on Zazzle.com) such as postcards, stamps, shirts, and mugs, featuring the logo design. These items were made available on pollinators.info, through a link to Zazzle.com.

In the summer of 2011, the author sent postcards featuring the pollinators.info logo to 22 nature centers within a 3-hour driving distance of her residence. Postcards invited recipients to visit the site, use it in their outreach activities, and contact the author if they were interested in free public presentations about pollinators.

The author emailed several online newsletters and offered to write free pollinator-related articles, and applied to be featured as Blog of the Week on the blog of Birds and Blooms magazine. A post was also submitted to the blog “Garden Grab”, which showcases garden-related posts with outstanding photographs.

Google Analytics was established for pollinators.info to monitor site visits, starting on July 1, 2011. Two Google AdWords campaigns were conducted between July 1, 2011, and January 31, 2012, to generate interest in the site and increase site visits.

The free pollinators.info newsletter was first published on July 2, 2011. Initially, subscribers received the free e-booklet, “Killer Bees: An Essential Guide,” written by the author. Starting in December, 2011, subscribers were also given a free chapter of the e-booklet, “Pollinated Sweets: Seasonal Desserts Made Possible by Pollinators,” which was available for sale on the site, and also written by the author. This e-booklet was also listed for sale on Google Books and eLibrary.

Newsletters were published via email weekly, and included links to the week’s posts, information about pollinators and/or plants from around the world, and site statistics (obtained from Google Analytics). Subscribers also received a monthly theme message, with links to several of the site’s posts on a particular topic (such as beetles).

The Pollinators Info Twitter account was created on July 21, 2011. Several tweets per week alerted subscribers to new posts and included links to each. On July 23, 2011, the author created a YouTube channel for pollinators.info to showcase short videos of pollinators (http://www.youtube.com/user/pollinatorsinfo). Video reviews of pollinator-related books were added to the channel soon after its launch.

On August 1, 2011, the first podcast was made available, and featured an interview with a pollinator scientist and a free downloadable transcript. Podcasts were available on the first of each month thereafter. The pollinators.info podcast feed was added to the podcast search sites TeachOutLoud, Podfeed.net, and Digital Podcast.

The author was interviewed about pollinators.info by Julie Tennis, the author of the blog, BeeMentor.com, on November 8, 2011.

On January 29, 2012, the author created a Flickr photostream to showcase her pollinator-related photographs and promote the site

(http://www.flickr.com/photos/pollinatorsinfo/). On February 10, 2012, the author started the "Pollinators Info bumble bee photo group" on Flickr, with the goal of collecting bumble bee photos from anyone, anywhere, to document bumble bee ranges and phenology, and promote Pollinators Info. Announcement emails about the photo group were sent to 51 nature centers and natural history museums in the USA and UK, inviting them to participate as part of their outreach activities. http://www.flickr.com/groups/bumbles/.

Results

A total of 240 posts were published in 34 categories between May 13, 2011 and February 13, 2012 (Appendix B). Twenty-six of these posts contained links to free downloads (Appendix C). Five organizations requested pollinator presentations (Table 3.2), and three online newsletters accepted guest articles from the author in 2011 (Table 3.3 and Appendix D). Pollinators Info was featured as Blog of the Week on the blog of Birds and Blooms magazine on September 9, 2011 (http://birdsandbloomsblog.com/2011/09/09/blog-of-the-week-pollinators-info/). Garden Grab featured the post "Plant Profiles: Barrel Cactus" on their site in 2011, but their archives are no longer available for the month in which this post was featured.

Pollinators Info received a total of 91 legitimate (non-spam) comments between May 13, 2011 and February 13, 2012. Visitor comments were often in the form of questions to the author, or were in response to a question posed by the author in a post. Visitors also emailed the author directly with comments or questions. See Appendix E for a selection of visitor comments and dialog between the author and readers.

According to Google Analytics, pollinators.info received a total of 10,246 visits from 8,028 unique visitors (IP addresses) between May 13, 2011 and February 13, 2012. Site visitation varied per month, (Fig. 3.2) with the lowest in October, 2011, and

the highest in November, 2011. Site visitors arrived from every major region in the world, from all continents, and 131 countries (Appendix F). Pollinators.info was in the top 100 natural history blogs in the world on the Nature Blog Network on February 13, 2012 (number 86 out of 551 in the Natural History category, and number 348 out of 1,953 in all categories). The site rose in Google page rank since its launch, and was within the first 5 sites listed for several keywords as of February 21, 2012 (Table 3.4).

Between May 13, 2011 and February 13, 2012 there were 20,363 page views, with an average number of pages viewed per visit of 1.99. Visitors spent an average of 2min, 30s on the site. Of the total visits, 621 (0.06%) were from mobile devices of 58 types. The most common method of finding pollinators.info was via Google keyword search. The most visited page was the one giving information about the author (Author), and the most visited post was “Book Interview: Bee Basics.”

The use of Google AdWords resulted in increased site visitation during two ad campaigns. One campaign advertised the post, “Victoria’s Secret loves pollinators (even if they don’t realize it)” during July, 2011. This campaign resulted in a peak of 173 visits on July 5, which was higher than the total number of visits during the 5 days after the end of the campaign (164). A second ad campaign, directing people to the site so they could learn how to help pollinators, resulted in a peak of 133 visits on December 11, 2011, which was higher than the total visits during the 3 days following the end of the campaign (115).

A total of 188 people were subscribed to the newsletter on February 13, 2011, and 10 people (0.05%) had unsubscribed. An average of 46% of subscribers opened the weekly newsletter, and 54% was the highest open rate recorded. Newsletter subscribers came from 14 countries (Table 3.5), with the highest numbers from the United States. Not all subscribers were from primarily English-speaking countries. The number of

newsletter subscribers increased continuously during the months of July, 2011 through January, 2012 (Fig. 3.3).

As of February 13, 2012, a total of 92 tweets were sent from pollinators.info, and 115 people were following pollinators.info on Twitter. The pollinators.info YouTube channel contained 17 videos, and received a total of 1,098 views (Table 3.6). The Flickr photostream contained 73 photos, and had been viewed approximately 55 times. The Flickr bumble bee photo group had 10 members, and the group photo pool contained 5 photos from the author and 8 from members. A total of 6 podcasts were published, the transcripts of which are available in Appendix G.

Discussion

The combined use of several social media platforms met the goals for Pollinators Info. The primary goal was to educate the public, and visitor comments and Google page rank increases attest that the site was used as a source of information about pollinators. Another goal for the site was that it would reach an international audience, which was accomplished, based on reports from Google Analytics. Finally, the author wanted visitors to view the site as trustworthy. This is more difficult to measure, but comments left on the site and in emails to the author indicate that visitors believe they can trust the site's content.

The variation in site visitation across months was most likely due to posting frequency in all but one instance. According to Rowse and Garrett (2008), high site visitation is most strongly correlated with high post frequency and regularity in timing of posts. Post frequency on Pollinators Info was lowest during the month of the lowest site visitation (October). However, site visitation in December was low, without a corresponding low post frequency. This is most likely the result of potential visitors focusing on holiday shopping and travel, rather than visiting informational blogs.

Maintaining a high posting frequency is time- consuming. Each post on Pollinators Info required 10 - 60 min to complete. Maintaining the other social media platforms can also be time-intensive. These time commitments are a reasonable explanation for the low post frequency found among outreach blogs online. Without a regular posting schedule, a blog will be less likely to show up in Google keyword searches, and will be more difficult for potential visitors to locate.

Visitor comments on Pollinators Info increased in frequency between May 13, 2011, and February 13, 2012. However, comment frequency was still less than one per week by February, 2012. This is possibly due to the youth of the site, and the corresponding low visitor numbers. Although the site has experienced increased visitation in its 9 months since launch, the average daily visitor numbers are still low. Pollinators Info received an average of approximately 60 visits per day (in February, 2012), which can be compared to other natural history blogs on the Nature Blog Network that receive an average of more than 1,000 visits daily. Rowse and Garrett (2008) stated that an average daily visitor number of 1,000 can take years to achieve.

The number of countries visiting Pollinators Info was a surprise, considering that the site is written in English. However, free online translation sites (like Google Translate) allow visitors to read almost any site in their own language. The author attributes the international interest in the site to posts on pollinators from all over the world.

An average visit duration of 2 min 30 s indicates that visitors were interacting positively with Pollinators Info. Rowse and Garrett (2008) suggested that visit duration is an indicator of the usefulness of a site, and that visits longer than 1 min are above average. Pollinators Info newsletter subscriptions, Twitter followers, and YouTube and Flickr views have increased since their launch, which also suggests that the public is interested in Pollinators Info content, and in continued interaction with the site.

Pollinators Info is still a young site. However, the results of frequent posting and integrating several social media platforms were favorable. The site is growing, based on average daily visit numbers, increased newsletter subscribers, and an increase in visitor comments. The author attributes this growth to the integration of several social media platforms. First, a high weekly post frequency on the blog makes Pollinators Info more likely to be shown among search engine results. The YouTube channel, Twitter feed, and Flickr stream are all prominently advertised on the site. Also, the profiles for Pollinators Info on YouTube, Twitter, and Flickr direct readers back to www.pollinators.info to learn more about pollinators.

In this manner, Pollinators Info is advertised not only when someone performs a keyword search for a pollinator, but also every time they find the site's tweets, videos, or photos through searches for those media. For instance, an internet user searching for information about bumble bees might not see the blog for Pollinators Info in their search results, but they might see photos or videos of bumble bees from the Pollinators Info YouTube channel or Flickr photostream, and be directed to the site via those media.

Social media platforms are increasing in popularity. This, coupled with the ease with which they can be set up and maintained, makes them ideal for meeting organizations' outreach goals. There is a need for translation between the scientific and lay communities that could be filled with outreach activities that use social media. For instance, blogs can make science topics more accessible to the lay public (Miller and Pole 2010, Minol et al. 2007). According to Bonetta (2007), science blogs are important because they provide the lay public with personality and authoritative content, which are also valued by readers.

These results support the suggestion by Rowse and Garrett (2008) that integration of social media is one key to blog success. In the case of Pollinators Info, blog success was measured by increases in traffic, comments, subscribers, followers,

and views of photos and videos. These are of direct benefit to the public, via education and free resources. However, most outreach blogs online appear to be missing the opportunities offered by social media. Outreach programs are encouraged to determine which social media platforms work best for them, then integrate them to reach, and engage with, a larger audience.

Tables and Figures

Figure 3.1. Pollinators.info logo.

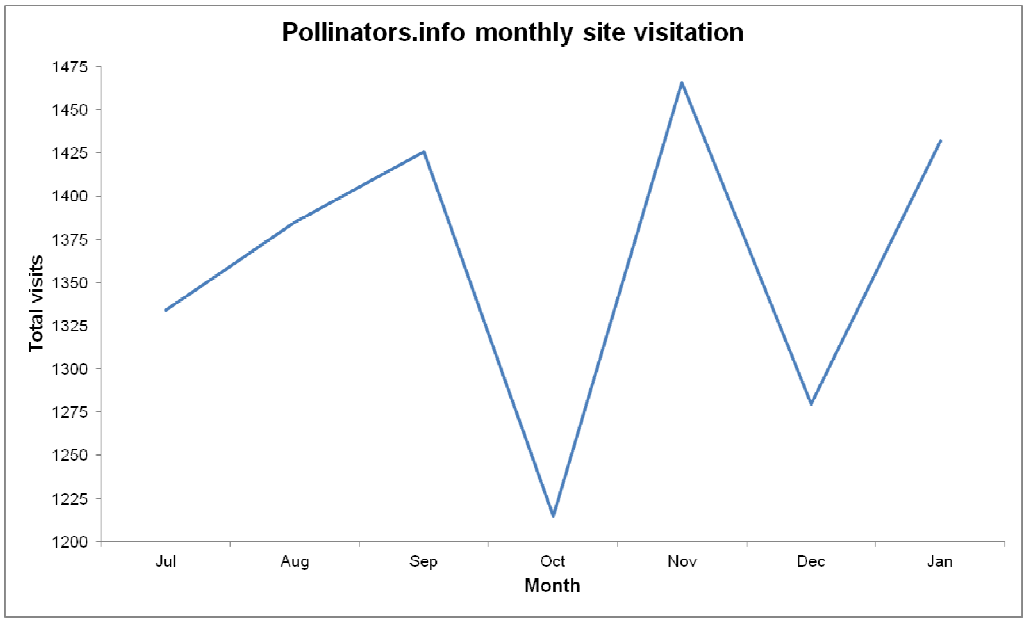


Figure 3.2. Monthly site visitation for pollinators.info.

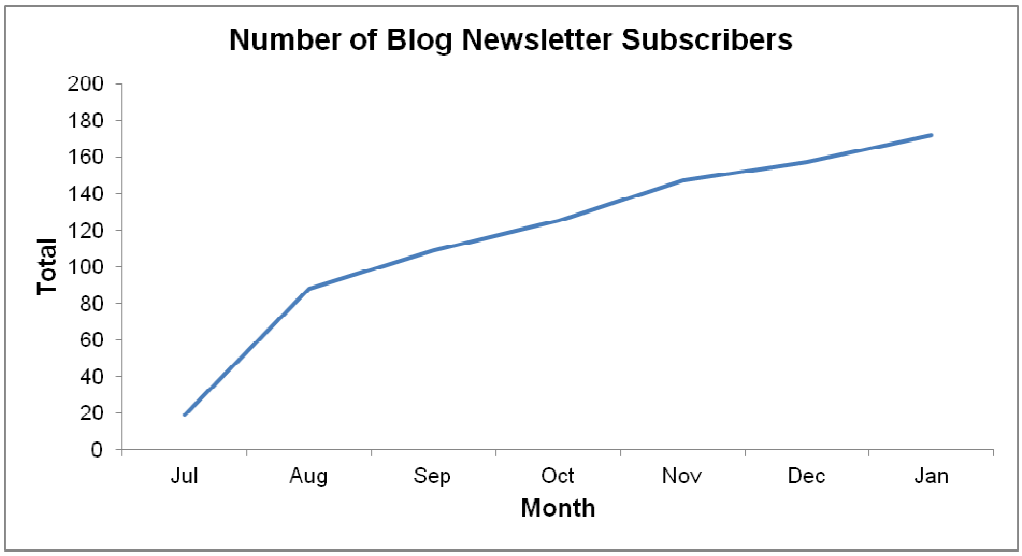


Figure 3.3. Increase in number of pollinators.info newsletter subscribers from July 1, 2011 – January 31, 2012.

Table 3.1. Results of Google Search for “nature center” or “natural history museum” and “blog,” on February 13, 2012. Organizations listed were within the first 5 pages of search results, and an “X” indicates whether the social media platform or feature was utilized on either the blog roll, or the home page for the organization. “Freq.” denotes average blog post frequency per month during the months of August, 2011, through January, 2012.

Organization	Location	Blog	Social Buttons	RSS	Comments	Freq.
Pfeiffer Nature Center & Foundation http://pfeiffernaturecenter.org/nature-blog/our-history/blog/	Portville, NY	X	X	X	X	1.3
Carpenter Nature Center http://carpenternaturecenter.org/blog/	Hastings, MN	X	X		X	0.0
Vashon Nature Center http://www.vashonnaturecenter.org/blog/	Vashon Island, WA	X	X	X	X	4.0
Ogden Nature Center http://www.ogdennaturecenter.org/about-onc/onc-blog	Ogden, UT	X	X		X	0.5
Osborne Welcome and Nature Center http://osbornenaturecenter.blogspot.com/	Elkader, IA	X	X	X	X	0.3
Chik- Wauk Museum and Nature Center http://www.chikwauk.com/blog/	Grand Marais, MN	X	X		X	2.3
Western North Carolina Nature Center http://wildwnc.wordpress.com/	Asheville, NC	X	X	X	X	4.5
Catoctin Creek Park and Nature Center http://catoctincreek.blogspot.com/	Middletown, MD	X	X		X	6.7
Sam Noble Museum http://www.snomnh.ou.edu/blog/	Norman, OK	X	X	X	X	0.2
Natural History Museum http://www.nhm.ac.uk/natureplus/index.jspa	London, England	X	X	X	X	>30
University of Kansas Natural History Museum http://naturalhistory.ku.edu/	Lawrence, KS	X			X	0.0
American Museum of Natural History http://www.amnh.org/news/	New York, NY	X	X	X		11.7
Slater Museum of Natural History http://slatermuseum.blogspot.com/	Tacoma, WA	X	X		X	1.8

Table 3.2. Organizations to which the author gave pollinator presentations in response to post card mailings and email notifications.

Organization	Date
South Carolina Midland Naturalists	November 15, 2011
Georgia Native Plant Society	October 15, 2011
Gwinnett Environmental and Heritage Center	September 24, 2011
Fulton County Cooperative Extension	September 23, 2011
Athens Permaculture Study Group	July 25, 2011

Table 3.3. Guest articles about pollinators written by the author in response to email offers.

Publication	Article Title	Time
Georgia Department of Natural Resources, online newsletter	"Native bees deserve the buzz."	August, 2011
Arizona Federation of Garden Clubs, Greenleaf Bulletin	"Ready, Set Grow!"	September, 2011
Kentucky Society of Natural History, Kentucky Naturalist News	"The importance of bees."	Summer, 2011

Table 3.4. Pollinators.info Google page rank for target keywords, as of February 21, 2012. Only showing keywords for which the site ranks on the first page.

Keyword	Google Page	Rank on Page
small mammal pollinators	1	1-4
butterfly pollinators	1	1-3
wasp pollinators	1	1
beetle pollinators	1	1
reptile pollinators	1	1
mammal pollinators	1	2-3
stingless honeybees	1	2-3
honeycreeper pollinators	1	2
reptile pollination	1	2
pollinator gardening	1	2
moth pollinators	1	3-4
bat pollinators	1	3
bird pollinators	1	3
fly pollinators	1	3
endangered pollinators	1	5-6
hummingbird pollinators	1	5

Table 3.5. Countries in which pollinators.info newsletter subscribers live. The countries of subscribers in the “unknown” category could not be located using their email address.

Country	Number of Subscribers
United States	126
unknown	34
Canada	6
India	4
United Kingdom	2
Australia	2
Ireland	2
New Zealand	1
Thailand	1
Iran	1
Malaysia	1
Lebanon	1
France	1
South Africa	1
Costa Rica	1

Table 3.6. Videos on pollinators.info's YouTube channel.

Video Title	Running Time (min:s)	Number of Views
Stingless honeybees- Trigona 2	0:14	127
Stingless honeybees- Trigona 1	0:19	115
Come home, honey bees!	0:30	109
Stingless honeybees- Melipona 2	0:34	89
Stingless honeybees- Melipona 1	0:29	87
Carpenter bee nectar robbing	0:34	84
Bumble bee drinking nectar	0:19	79
Stingless honeybees- Trigona 3	0:08	69
Video book review: Attracting Native Pollinators	8:14	65
Honey bees swarming	0:34	56
Black swallowtail butterfly on sunflower	0:29	47
Valley carpenter bee male defending his territory	0:30	44
Video book review: National Wildlife Federation Field Guide to Wildflowers of North America	8:45	40
Native bee collects sunflower pollen	0:38	23
Sunflower bee on native sunflower	0:14	21
Shiny green sweat bee	0:11	18
Video book review: Bats in Question	7:26	12

REFERENCES

Ashton, Carolyn, Robin Galloway, and Virginia Bourdeau. 2010. Can blogging benefit staff & youth in 4-H camp programs? Journal of Extension 48(4) article #4IAW6.

Barrows, E.M., M.R. Chabot, C.D. Michener, and T.P. Snyder. 1976. Foraging and mating behavior in *Perdita texana* (Hymenoptera: Andrenidae). Journal of the Kansas Entomological Society 49(2):275-279.

Bonetta, Laura. 2007. Scientists enter the blogosphere. Cell 129:443-445.

Bouseman, J.K. 1982. *Andrena haynesi* Viereck and Cockerell in Illinois: a sunflower bee new to the eastern United States. Journal of the Kansas Entomological Society 55(1):75-76.

Browne, Stephen J., and Nicholas J. Aebischer. 2003. Temporal changes in the migration phenology of turtle doves *Streptopelia turtur* in Britain, based on sightings from coastal bird observatories. Journal of Avian Biology 34: 65-71.

Cameron, Sydney, Jeffrey D. Lozier, James P. Strange, Jonathan B. Koch, Nils Cordes, Leellan F. Solter, and Terry L. Griswold. 2011. Patterns of widespread decline in North American bumble bees. PNAS 108(2): 662-667.

Cane, J.H. 1995. Notes on the nesting biology of *Svastra atripes atrimitra* (LaBerge) (Hymenoptera: Apidae) Journal of the Kansas Entomological Society 68(2):238-240.

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

Colla, S.R., and 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.

Danforth, Bryan N. 1999. Emergence dynamics and bet hedging in a desert bee, *Perdita portalis*. Proceedings of the Royal Society of London B. 266: 1985-1994.

De La Hoz, Juan Di Trani. 2006. Phenology of *Bombus pennsylvanicus sonorus* Say (Hymenoptera: Apidae) in central Mexico. Neotropical Entomology 35(5): 588-595.

DiPietro, Lisa, and Michelle Miller. 2009. Extending expertise through conference calls and blogging. Journal of Extension 47(6) article #6TOT6.

Faegri, K., and L. van der Pijl. 1979. The principles of pollination ecology. third ed. Frankfurt: Pergamon Press.

Free, J.B. 1993. Insect pollination of crops. Academic Press; London, UK; 684 pp.

Gillman, Jeffrey, Linda Chaler-Scott, Holly Scoggins, and Bert Cregg. 2011. A successful multi-institutional blog for transferring garden and landscape information to the public. Journal of Extension 49(6) article #6IAW3.

Goodell, K. and J.D. Thomson. 1997. Comparison of pollen removal and deposition by honey bees and bumble bees visiting apple. Acta Horticulturae 437:103-107.

Goulson, Dave. 2010. Bumblebees: behaviour, ecology, and conservation. 2nd Ed. Oxford University Press; London UK: 317 pp.

Goulson, D., G.C. Lye, and B. Darvill. 2008. Decline and conservation of bumble bees. Annual Review of Entomology 53: 191-208.

Greenleaf, S.S., and C. Kremen. 2006. Wild bees enhance honey bees' pollination of hybrid sunflower. PNAS 103(37):13890-13895.

Grixti, Jennifer C., Lisa T. Wong, Sydney A. Cameron, and Colin Favret. 2009. Decline of bumble bees (*Bombus*) in the North American Midwest. Biological Conservation 142: 75-84.

Hagen, Melanie, Martin Wikelski, and W. Daniel Kissling. 2011. Space use of bumblebees (*Bombus* spp.) revealed by radio-tracking. PLOS One 6(5):e19997.

Heinrich, B. 1979. Bumble bee economics. Harvard University Press; Cambridge MA: 249 pp.

Hobbes, G.A. 1967. Ecology of species of *Bombus* Latr. (Hymenoptera: Apidae) in southern Alberta. VI. Subgenus *Pyrobombus* Canadian Entomologist 99:1271-1292.

Holm, S.N. 1966. The utilization and management of bumblebees for red clover and alfalfa seed production. Annual Review of Entomology 11:155-182.

Jones, Marcus A., John E. Kaminski, Nick E. Christians, and Mark D. Hoffmann. 2011. Using blogs to disseminate information in the turfgrass industry. Journal of Extension 49(1) article #1RIB7.

Jordano, P. 1987. Patterns of mutualistic interactions in pollination and seed dispersal: connectance, dependence asymmetries, and coevolution. American Naturalist 129:657-677.

Kearns, C.A. and J.D. Thomson. 2001. The natural history of bumblebees: a sourcebook for investigators. University Press of Colorado; Boulder, CO: 130pp.

Knight, M.E., A.P. Martin, S. Bishop, J. Osborne, R.J. Hale, R.A. Sanderson, and D. Goulson. 2005. An interspecific comparison of foraging range and nest density of four bumblebee (*Bombus*) species. Molecular Ecology 14: 1811-1820.

Kosior, Andrzej, Waldemar Celary, Pawel Olejniczak, Jan Fijal, Wieslaw Krol, Wojciech Solarz, and Piotr Plonka. 2007. The decline of the bumble bees and cuckoo bees (Hymenoptera: Apidae: Bombini) of Western and Central Europe. Oryx 41(1): 79-88.

Kremen, C., N.M. Williams, and R.W. Thorp. 2002. Crop pollination from native bees at risk from agricultural intensification. Proceedings of the National Academy of Sciences 99(26): 16812-16816.

Kwon, Y.J. and S. Saeed. 2003. Effect of temperature on the foraging activity of *Bombus terrestris* L. (Hymenoptera: Apidae) on greenhouse hot pepper (*Capsicum annuum* L.). Applied Entomology and Zoology 38(3):275-280.

Matteson, Kevin C. and Gail A. Langellotto. 2009. Bumble bee abundance in New York City community gardens: implications for urban agriculture. Cities and the Environment 2(1):article 5.

McIver, J., R. Thorp, and K. Erickson. 2009. Pollinators of the invasive plant, yellow starthistle (*Centauria solstitialis*), in north-eastern Oregon, USA. Weed Biology and Management 9:137-145.

Meisels, S. and H. Chaisson. 1997. Effectiveness of *Bombus impatiens* Cr. as pollinators of greenhouse sweet peppers (*Capsicum annuum* L.) Acta Horticulturae 437:425-429.

Michener, C.D. The Bees of the World. Baltimore: The Johns Hopkins University Press.

Miller, Edward Allen, Antoinette Pole. 2010. Diagnosis blog: checking up on health blogs in the blogosphere. American Journal of Public Health 100(8):1514-1519.

Milliron, H.E. 1973. A monograph of the western hemisphere bumblebees (Hymenoptera: Apidae, Bombinae) III. Memoirs of the Entomological Society of Canada. 91:239-333.

Minol, Klaus, Gerd Spelsberg, Elisabeth Schulte, and Nicholas Morris. 2007. Portals, blogs, and co.: the role of the internet as a medium of science communication. Biotechnology Journal 2:1129-1140.

Muchhala, N. 2006. Nectar bat stows huge tongue in rib cage. Nature 444:701-702.

Osborne, J.L., S.J. Clark, R.J. Morris, I.H. Williams, J.R. Riley, A.D. Smith, D.R. Reynolds, and A.S. Edwards. 1999. A landscape-scale study of bumble bee foraging range and constancy, using harmonic radar. Journal of Applied Ecology 36: 519-533.

Parker, F.D. 1981. How efficient are bees in pollinating sunflowers? Journal of the Kansas Entomological Society 54(1):61-67.

Parker, F.D., V.J. Tepedino, and G.E. Bohart. 1981. Notes on the biology of a common sunflower bee, *Melissodes* (*Eumelissodes*) *agilis* Cresson. New York Entomological Society 89(1):43-52.

Plath, O.E. 1934. Bumblebees and their ways. Macmillan, New York. 201 pp.

Posey, A.F., R.W. Katayama, and J.G. Burleigh. 1986. The abundance and daily visitation patterns of bees (Hymenoptera: Apoidea) on oilseed sunflower, *Helianthus*

annuus L., in southeastern Arkansas. Journal of the Kansas Entomological Society 59(3):494-499.

Pyke, Graham H., David W. Inouye, and James D. Thomson. 2011. Activity and abundance of bumble bees near Crested Butte, Colorado: diel, seasonal, and elevation effects. Ecological Entomology 36:511-521.

Rowse, Darren, and Chris Garrett. 2008. Problogger: secrets for blogging your way to a six-figure income. Wiley, Indianapolis 220 pgs.

Rozen, J.G. 1983. Nesting biology of the bee *Svastra sabinensis* (Hymenoptera: Anthophoridae). New York Entomological Society 91(3):264-268.

Thorp, R.W., and J.R. Estes. 1995. Intrafloral behavior of bees on flowers of *Cassia fasciculata*. Journal of the Kansas Entomological Society 48(2):175-184.

Sapp, Lara, and Keith Cogdill. 2010. Blogging in support of health information outreach. Medical Reference Services Quarterly 29:240-248.

Scheunert, Agnes, Andreas Zahn, and Andreas Kiefer. 2010. Phenology and roosting habits of the Central European grey long-eared bat *Plecotus austriacus* (Fischer 1829). European Journal of Wildlife Research 56: 435-442.

Stanghellini, M.S., J.T. Ambrose, and J.R. Schultheis. 1998. Seed production in watermelon: a comparison between two commercially available pollinators. HortScience 33(1): 28-30.

Stanghellini, Michael S., J.T. Ambrose, and Jonathan R. Schultheis. 2002. Diurnal activity, floral visitation and pollen deposition by honey bees and bumble bees on field-grown cucumber and watermelon. Journal of Apicultural Research 40(1-2): 27-34.

Stiles, F. Gary. 1975. Ecology, flowering phenology, and hummingbird pollination of some Costa Rican *Heliconia* species. Ecology 56: 285-301.

Stubbs, C.S. and F.A. Drummond. 1997. Blueberry and cranberry (Vaccinium spp.) pollination: a comparison of managed and native bee foraging behavior. Acta Horticulturae 437:341-344.

Sublet, Virginia, Christina Spring, and John Howard. 2011. Does social media improve communication? Evaluating the NIOSH science blog. American Journal of Industrial Medicine 54:384-394.

Walther-Hellwig, K., and R. Frankl. 2000. Foraging habitats and foraging distances of bumblebees, *Bombus* spp. (Hym., Apidae) in an agricultural landscape. Journal of Applied Entomology 124: 299-306.

Waser, N.M., L. Chittka, M.V. Price, N.M. Williams, and J. Ollerton. 1996. Generalization in pollination systems, and why it matters. Ecology 77(4):1043-1060.

Wee, Yeow Chin. 2011. Citizen science and the monitoring of hornbills in Singapore. The Raffles Bulletin of Zoology, Supplement 24:23-25.

Willmer, P.G., A.A. Bataw, and J.P. Hughes. 1994. The superiority of bumblebees as pollinators: insect visits to raspberry flowers. Ecological Entomology 19:271-284.

Wilson, Daniel T., and Susan S. Yowell. 2008. Resourceful blogging: using blogs for information sharing. Medical Reference Services Quarterly 27(2):211-220.

Winfree, R., N.M. Williams, J. Dushoff, and C. Kremen. 2007. Native bees provide insurance against ongoing honey bee losses. Ecology Letters 10: 1105-1113.

APPENDIX A- POST EXAMPLES

#1- Pollinator Profile: Round Island Skink

Vulnerable!

Photo © Dennis Hansen

The Round Island skink, also known as Telfair's skink, and *Leiolopisma telfairii*, was once endemic to Mauritius and its islets. It is now found only on the 373-acre (151ha) Round Island, off of Mauritius' North coast.

Round Island skinks are the largest lizard species on the island, reaching about 12-15" (30-40cm) from nose to tail. Adults use their strong legs to dig burrows in which they hide or nest, usually in vegetated habitats. These skinks tend to spend most of their time on the ground, and are active primarily during the day.

Round Island is one of the last strongholds of a palm savanna habitat that was once also present in the lowlands of northern and western Mauritius. According to David Bullock (see citation below), this habitat contains some of the world's rarest palms and reptiles. The Round Island skink is now rarely found outside this unique habitat.

The Round Island skink is omnivorous, but is an important pollinator for palms and other plants native to the island. The individual in the photo above is resting on a palm, and you can see yellow pollen dusted on the top of its head.

Invasive rats, rabbits, and goats are largely to blame for the destruction of the palm savanna habitat on Mauritius. Like many other endangered species, habitat

destruction has been one of the greatest threats to the Round Island skink. The International Union for Conservation of Nature (IUCN) has listed this skink as Vulnerable since 1986.

Round Island has been better preserved than other islets, mostly due to its greater distance from the mainland. I call it a conservation success story that invasive rats, rabbits, and goats have been eradicated from the island. According to Angelo Pernetta and colleagues (citation below), the Round Island skink might soon be reintroduced to islands on which it was extirpated.

The history and conservation of the Round Island skink are examples of the connections between plants and their pollinators. Read more pollinator stories in the Pollinator Profiles category!

Reptiles are not common as pollinators around the world, but their stories are fascinating! Read more in the Reptiles category.

Bullock, David. 1986. The ecology and conservation of reptiles on Round Island and Gunner's Quoin, Mauritius. Biological Conservation 37:135-156.

Pernetta, Angelo P., Diana J. Bell, and Carl G. Jones. 2005. Macro- and microhabitat use of Telfair's skink (Leiolopisma telfairii) on Round Island, Mauritius: implications for their translocation. Acta Oecologica 28:313-323.

Have you seen reptile pollinators? Share your story with us in the comments below!

Many thanks to Dr. Dennis Hansen for allowing me the use of his photograph!

If you'd like to learn more about reptiles on Mauritius, give this book a try: Amphibians and Reptiles of Madagascar, the Mascarene, the Seychelles, and the Comoro Islands.

#2- Take Action! Little ways you can help pollinators- #6

Use natives!


Photo © Athena Rayne Anderson 2011

Pollinators get the most benefit from native plants, no matter where you live. There's a lot of research to back this up- native plants are better for pollinators than non-natives. Here are a few reasons why:

1. Native plants are more recognizable to pollinators as food sources.
2. Native plants tend to provide more nectar and pollen than ornamental varieties.
3. Native plants are part of your local ecosystem, and establishing them can also provide shelter for pollinators.

Native plants are also better for YOU, because they're easier and less expensive to maintain. They are adapted to your local climate, soil, and light conditions, so don't need extras like irrigation and fertilizer.

Do you grow natives instead of non-natives? What's your opinion about replacing non-native plants with native plants in gardens and public places to benefit pollinators and other wildlife? Share your ideas with us below!

This post is in a series, and you can read the others here:

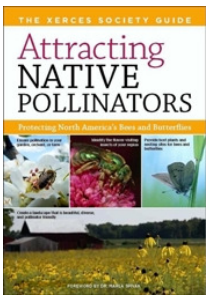
- Use native grasses
- Don't mulch
- Keep something blooming
- Minimize chemical use in your yard
- Start a pollinator garden plot

Find out more ways you can help pollinators in the Actions and Gardening categories!

Get FREE STUFF and weekly site updates when you subscribe to the free pollinators.info e-newsletter!

Get to know your native plants with a Peterson Field Guide! This series of guides is one of my favorites for just about everything! For a group as large as "wildflowers," Peterson's guides are divided into regions.

#3- Book Interview: Attracting Native Pollinators



I was fortunate to get an email interview this week with Dr. Scott Hoffman Black, co-author of the new book Attracting Native Pollinators. Doctor Black is the Executive Director of the Xerces Society for Invertebrate Conservation, which published the book, and he's also the Chair of the Butterfly Specialist Group for the International Union for Conservation of Nature (IUCN).

My goal with the interview was to get some insight into the background of the book, why it's such a milestone in pollination literature, and how it can be a great resource for YOU! Below is the transcript of our interview...

Athena (ARA): What was Xerces main goal with the publication of Attracting Native Pollinators?

Dr. Black (SHB): The goal of the book is to get people to take action to improve habitat for pollinators. Although there is a lot of information out there about the decline of pollinators there was no single resource that provided all of the information people needed to understand, start to identify, and work to protect pollinators. Our goal was to produce just such a comprehensive resource.

ARA: What was your target audience for the book?

SHB: The target audience for the book is very broad. Gardeners, farmers, park managers, land managers and average homeowners --everyone. The neat thing about pollinator conservation is that it is equal opportunity. Whether you have a window box, a backyard garden or you manage a park or a farm there are actions you can take to provide for these important animals.

ARA: From what I can tell, this is the first book with a beginner-friendly ID guide for native bees. Why do you think it took until 2011 for a book of this kind to be published?

SHB: It is only fairly recently that bees have come into the mainstream. Although there has been a demand for guides for butterflies for decades it is only recently that there has been an interest in bees. Also bees are harder to identify then most butterflies. Having more than 4,000 species in the US (butterflies have 800), with many of them hard to tell apart, provides a special challenge in producing a fully comprehensive guide to bee species. In the end we developed a guide to the major groups of bees (Genera) what we hope will help people to start to identify these animals. Once people start to look and see that there may be as many as a dozen different kinds of bees visiting flowers in their yards they may better appreciate their importance.

ARA: What was the biggest challenge in getting the book together?

SHB: This was a big undertaking. One of the biggest challenges was to produce a book with this much information while still keeping it accessible and interesting.

ARA: What has been most rewarding about working on this book and/or getting it published?

SHB: What is most rewarding is the positive response. We have heard from hundreds of people that have congratulated us on a job well- done. Many of these responses include information on how people are using the book to improve habitat for pollinators.

ARA: Why do you think it's important for people to learn about native pollinators, especially native bees?

SHB: Pollinators are vitally important to humans and to the ecosystems that we depend on. Pollinators – mostly insects -- are needed for the reproduction of nearly three quarters of the world's flowering plants. This includes more than two-thirds of the world's crops whose fruits and seeds provide over 30% of the foods and beverages that we consume. Although many of our staples –corn, wheat, and rice – are wind- pollinated,

many of our most nutritious and delicious foods – apples, berries and many vegetables- are insect- pollinated. Dinner would not be the same without them.

Unfortunately this service is at risk. Habitat loss, alteration, and fragmentation, as well as pesticide use, all contribute to pollinator declines. Honey bee declines remain in the news, but many native bees are potentially faring even worse. For example, in the past decade alone, several bumble bees, including several common species such as the rusty- patched bumble bee, have been pushed close to extinction.

ARA: What do you see as the biggest challenge in educating people about pollinators?

SHB: In my opinion educating people about pollinators is only really successful if you get people to take action for pollinators. It is all well and good for people to understand the problem but if people do nothing it does not do much good. But getting people to take action can be difficult. People are busy. Whether you are a farmer who is working extremely long hours to ensure your crops produce a maximum yield or a suburban family working while also getting kids to school and soccer practice many people do not have a lot of free time. That is why we try to make it as easy as possible for people to take the steps that will help pollinators. If we can get people to take small steps these add up. Also once people get interested they often do more and more.

ARA: Could you list 3-5 things that people could do on their property, or in their lives, to help pollinators?

SHB: The best way to attract and support healthy pollinator populations is to ensure a rich, diverse plant community. By protecting existing habitat, restoring degraded areas, and creating new foraging and nesting sites, we can provide for the needs of pollinators. Whether you are working in a small yard or on a large expanse of land, the conditions that you will want to create all have these features:

1. A diversity of native plants whose blooming times overlap to provide flowers for foraging throughout the seasons. In any location, native flowers, which are adapted to local soils and climates, are the best source of nectar and pollen for native pollinators. In residential yards and gardens, heirloom plant varieties can also be very beneficial.
2. Nesting and egg-laying sites, with appropriate nesting materials. Bees require sites in the ground or woody vegetation as well as nesting materials, and butterflies need appropriate host plants for their caterpillars.
3. A landscape free of poisonous chemicals. The use of pesticides in gardens, on farms, and in managed landscapes is a major threat to pollinators. Insecticides kill and injure pollinator insects directly, while herbicides can harm them by damaging the plants that offer them foraging and egg-laying opportunities. Avoid the use of pesticides in or near pollinator habitat.

You do not need to do all of this at once. You can start by adding a few flowering plants and avoiding the use of insecticides. Over time you can add more habitat until you have a diverse landscape that is both beautiful to look at and beneficial to pollinators.

The Xerces Society website has lots of great resources that can help you create a pollinator-friendly yard on their pollinator conservation page. Also their Pollinator Conservation Resource Center is a great source for info and ideas on plants selection and ways to start your own pollinator conservation project in your region of the U.S. or Canada!

#4- Victoria's Secret loves pollinators (even if they don't realize it!)

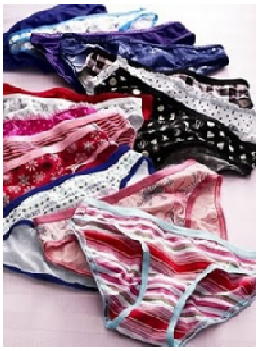
Have you ever seen one of these?

Photo© ChriKo 2008

How about one of these?

Photo© Athena Rayne Anderson 2011

Well, ok, what about these?



Ah-hah! So you've seen the panties, huh?

Well, now that I have your attention, check this out:


Photo © Chriko 2006

+


Photo © Athena Rayne Anderson 2011

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What's the mystery flower? When I was growing up, it was... "the fabric of our lives." Give up? It's COTTON!

Even though there are other materials added to our clothes sometimes (think polyester and spandex), most of what we wear nowadays is still made of cotton. I mean, it's hard to beat your favorite pair of jeans, right?

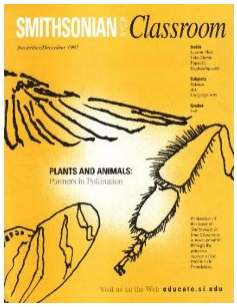
Cotton flowers are pollinated by a lot of animals, especially bees. After pollination, the ovary and seeds develop. After a while, the cotton boll (fruit) pops open to reveal the white fluff that we turn into denim, napkins, pillows, and... panties!

Can I get three cheers for pollinators?!

Know of another common product that depends on pollinators? Share it here!

If you liked this post, you might also enjoy the Bees and Agriculture categories and the Agriculture page. If you really liked it, subscribe to the free pollinators.info email newsletter and get FREE STUFF!

#5- Smithsonian Pollinators Curriculum: free download!



The Smithsonian In Your Classroom program (from the Smithsonian Institution) has a fun, free, curriculum to teach kids about pollinators!

The curriculum is called: Plants and Animals: Partners in Pollination, and it features the following:

1. a detailed introduction for you, the educator
2. 3 complete lessons for grades 4-9
3. printable worksheets and diagrams
4. resource list for more information

Just click on the curriculum title above to download it for free. You'll need Adobe Reader to see the file, but don't worry- download the Adobe Reader for free here.

Have you used any of these lessons? Offer your critique below so we can learn from you!

Get more free stuff in the Downloads category, and find more educational resources on the Education page!

Get FREE STUFF and weekly site updates when you subscribe to the free pollinators.info e-newsletter!

APPENDIX B- POSTS

Posts are usually filed under more than one category on the site, but are only listed in their most relevant category here, in an attempt to minimize confusion. Some categories are not listed individually, because the only posts they contain are listed under a different category. Several posts, advertising for merchandise or the e-book, are not included here.

List of Post Categories

1. Actions
2. Agriculture
3. Beekeeping
4. Bees
    a. Bumble bees
    b. Carpenter bees
    c. Honey bees
    d. Killer bees
    e. Solitary bees
    f. Stem-nesting bees
    g. Stingless honeybees
5. Beetles
6. Birds
    a. Honeycreepers

    b. Hummingbirds
7. Butterflies
8. Downloads
9. ebooks
10. Endangered
11. Flies
12. Gardening
13. General
14. Mammals
    a. Bats
    b. Small mammals
15. Moths
16. Plant Profiles
17. Podcasts
18. Pollination
19. Pollinator Profiles
20. Reptiles
21. Research
22. Reviews
23. Wasps

Posts in the Actions Category

1. Take Action! Little ways you can help pollinators- #1 (start a pollinator garden plot)
2. Take Action! Little ways you can help pollinators- #2 (minimize chemicals in your yard)

3. Take Action! Little ways you can help pollinators- #3 (keep something blooming)
4. Take Action! Little ways you can help pollinators- #4 (don't mulch)
5. Take Action! Little ways you can help pollinators- #5 (plant native grasses)
6. Take Action! Little ways you can help pollinators- #6 (plant natives)
7. 4 tips to help pollinators from your home in the city
8. Top 5 ways to help pollinators on your property
9. What have you done for them lately?
10. National Pollinator Week approaches!
11. Highways BEE Act- sign the petition!
12. Pollinators need water too!
13. Great Sunflower Project
14. Global Pollination Project
15. Adopt a Bat and get a plushie!
16. Artificial nests for native bees
17. Guelph Pollinator Park- interview
18. Video- Pollinator Hedgerows: There's a Plan for That
19. Find a native plant nursery
20. NEW! Flickr bumble bee group

Posts in the Agriculture Category

1. Victoria's Secret loves pollinators (even if they don't realize it!)
2. How many species of pollinator are managed for agriculture?
3. Godiva loves pollinators- even if they don't realize it!
4. Roadsides and margins as pollinator habitat
5. Using Farm Bill programs for pollinator conservation- document
6. Be a Bee Friendly Grower!

7. IPM and pollinators- document
8. Enhancing Nest Sites for Native Bee Crop Pollinators- document
9. Video from Native Pollinators in Agriculture Project
10. Farming for Bees- document
11. Improving forage for native bee crop pollinators
12. What pollinates pumpkins?
13. What pollinates apples?
14. What pollinates cranberries?
15. What pollinates oranges?
16. What pollinates pomegranates?

Posts in the Beekeeping Category

1. Colony Collapse- what is it?
2. Mayan beekeeping video

Posts in the Bees Category

1. Killer bees- what are they really?
2. Killer bees- in case of attack
3. Killer bees- attack physiology
4. Killer bees- can they be managed?
5. Native bees- what are they?
6. Bee? Wasp? Fly? How can you tell?
7. Bees in my yard? Won't they sting me?
8. Bees as pollinators
9. Honey bees in your walls?
10. How many honey bees in one hive?

11. Honey bees- my first stings!
12. Come home, honey bees!
13. Insect body parts- the head
14. Insect body parts- the thorax
15. Insect body parts- the abdomen
16. Bumble bee or carpenter bee?
17. Carpenter bees nesting in your walls?
18. Nests in the ground?
19. Managing Alternative Pollinators- book
20. It's a robber fly!
21. Stem-nesting pollinators!
22. Bug Girl's Blog- Eddie Izzard does the honey bee dance!
23. How to "get some" if you're a male carpenter bee
24. What if there were no bees?
25. New feature article in Georgia DNR newsletter!
26. Bees in Art website
27. How to keep bees from nesting in your house
28. Urban Bee Project
29. Artificial nests for native bees
30. Bumble bee pocket identification guides- documents
31. Make your own wooden bee nest- document
32. Raising bumble bees at home- a guide to getting started- document
33. Nests for native bees- document
34. Why do bees sting?
35. Bee prints for sale from Pencil and Leaf!
36. Of minis and giants (world's largest and smallest bees)

Posts in the Birds Category

1. Hummingbirds as pollinators

Posts in the Butterflies Category

1. Butterflies as pollinators
2. Get to know the butterflies and moths in your region!
3. Lesson Plan: The Life Cycle of a Butterfly
4. Video guides: skippers of the Northeast
5. Monarch LIVE: a distance learning adventure

Posts in the Endangered Category

1. Endangered Pollinators- pt 1
2. Endangered Pollinators- pt 2
3. Endangered Pollinators- pt 3

Posts in the Gardening Category

1. Gardening for pollinators
2. Non-native plants for pollinators?
3. Pollinator garden in progress
4. My first native sunflower is blooming!
5. Pollinator Partnership Regional Planting Guides
6. NAPPC Bee Smart App
7. Leafsnap App helps you identify plants!
8. USFWS: Attracting Pollinators to Your Garden (document)
9. Garden Variety Native Bees of North America- perpetual calendar
10. Gardening for Native Bees in Utah and Beyond- document

Posts in the General Category

1. UW Botany Outreach Store- pollinator poster!
2. 2011 Pollinator Week poster!
3. New pollination biology database
4. Pollinator Week video
5. pollinators.info birthday giveaways (monthly)
6. pollinators.info now has a YouTube channel!
7. Book Interview: “Attracting Native Pollinators”
8. Bees article in Kentucky Naturalist News!
9. New featured mini-article in Arizona Greenleaf Bulletin!
10. Pollinator habitats on military bases!
11. BeeSmart School Garden Kit is a great resource for teachers!
12. Bee Guardian Town!
13. pollinators.info in top 100 natural history blogs!
14. Video: “Pollinators- busy doing what?”
15. pollinators.info Flickr photostream! (notice of availability)
16. Native pollinators video from Penn State University’s Center for Pollinator Research
17. Book Interview: “Bee Basics”

Posts in the Mammals Category

1. Bats as pollinators
2. Marsupials as pollinators
3. Lemurs as pollinators in Madagascar
4. Bats LIVE: a distance learning adventure
5. Bats Are Pollinators Too- document

6. Bats: A Creativity Book for Young Conservationists- document

Posts in the Moths Category

1. Moths as pollinators
2. Moths trapped in ginger lilies

Posts in the Pollinator Profiles Category

1. Bumble bees
2. Sweat bees (Halictid bees)
3. Squash bees
4. Pollen wasps
5. Bay checkerspot butterfly
6. Sphinx moths
7. Bee-flies
8. Blue-tailed day gecko
9. Long-tongued flies
10. Ruby-throated hummingbird
11. Soldier beetles
12. Ailanthus webworm moths
13. Yucca moths
14. Senita moths
15. Kinkajou
16. Tarantula hawk wasp
17. Lesser long-nosed bat
18. White-winged dove
19. Lucifer hummingbird

20. Mariana fruit bat
21. Masked chafer beetle
22. Mason bees (*Osmia*)
23. ‘Apapane
24. Valley elderberry longhorned beetle
25. Spiny mice
26. Round Island skink
27. Stingless ‘Trigona’ honeybees
28. Stingless ‘Melipona’ honeybees
29. Greater long-nosed bat
30. Purple Honeycreeper

Posts in the Plant Profiles Category

1. Basil
2. Purple coneflower
3. Sunflowers
4. Barrel cactus
5. Milkweed
6. Maypop
7. Black-eyed Susans
8. Joshua tree
9. Senita cactus
10. Joe-pye weed
11. Holly
12. Black willow

Posts in the Pollination Category

1. What is pollination?
2. Pollinator Game
3. Pollination Syndromes- part 1 (water, wind, beetles)
4. Pollination Syndromes- part 2 (bees, butterflies, hummingbirds)
5. Pollination Syndromes- part 3 (flies, moths, bats)
6. Pollination Syndromes- part 4 (small mammals, honeycreepers, wasps)
7. Nectar replenishment
8. Nectar robbing
9. Pollination Glossary
10. What are pollinia? Pollen backpacks!
11. Prehistoric pollinators: scorpionflies did it before the birds and the bees!

Posts in the Podcasts Category

1. Podcasts (notice of availability on blog)
2. Pollinator Week podcasts
3. Episode 1 podcast available! (Interview with Dr. Stephen Buchmann about buzz pollination)
4. Episode 2 podcast available (Interview with Sam Droege about bee surveys on Cuba)
5. Episode 3 podcast: An interview with Dr. Nathan Muchhala (long-tongued bats)
6. Podcast Episode 4: Interview with Dr. Nat Holland (senita moths)
7. Podcast Episode 5: Interview with Dr. Ted Fleming (lesser long-nosed bats)
8. Podcast Episode 6: Interview with Dr. Robbin Thorp (endangered Franklin's bumble bee)
9. BeeMentor.com interviewed me!

Posts in the Research Category

1. Research Bite: The foraging specializations of individual bumble bees

Posts in the Reviews Category

1. Book & camera reviews
2. Product review- Attracting Native Pollinators: Protecting North America's Bees and Butterflies
3. Book Review: Pollinator Conservation Handbook
4. Book Review: The Forgotten Pollinators
5. Book Review: Letters From the Hive
6. Video Book Review: Attracting Native Pollinators
7. Video Book Review: NWF Field Guide to Wildflowers of North America
8. Book Review: Hummingbirds of North America
9. Video Book Review: Bats in Question

APPENDIX C- POSTS CONTAINING FREE DOWNLOADS

1. New booklet available! Bee Basics, from the Pollinator Partnership!
2. Pollinator-friendly practices- document
3. How do invasive species affect pollinators?
4. Pollinator Curriculum
5. How do pollinators affect sage grouse? Document
6. Bee crossword puzzle
7. Bee crossword puzzle answers
8. Hummingbird word search
9. Hummingbird word search solutions
10. Smithsonian pollinators curriculum- free download!
11. How do pollinators affect bears? Free document!
12. Native Pollinators- free document
13. Using Farm Bill programs for pollinator conservation- document
14. IPM and pollinators- document
15. Enhancing Nest Sites for Native Bee Crop Pollinators- document
16. Farming for Bees- document
17. Make your own wooden bee nest- document
18. Raising bumble bees at home- a guide to getting started- document
19. Nests for native bees- document
20. Gardening for Native Bees in Utah and Beyond- document
21. Bats Are Pollinators Too- document

22. Bats: A Creativity Book for Young Conservationists- document

23. All podcast posts contain a downloadable transcript

24. Pollinator Profile: Purple Honeycreeper

25. Pollinator Profile: ‘Apapane

26. Pollinator Profile: Round Island Skink

APPENDIX D- GUEST ARTICLES

#1- Georgia DNR online newsletter, August, 2011

Native bees deserve the buzz

Did you know that every third bite of food you eat is made possible by bees?

Most people know honey bees are important for pollinating fruits and vegetables, but did you know they're not the only bees that do this? There are a variety of fascinating and beautiful native bees that pollinate our crops and wild plants, too.

Honey bees were brought to North America by early European settlers. Most of what folks know about bees as a group was learned from honey bees. However, honey bees are very different from the majority of other bees in the world. For instance, most bees live solitary lives, rather than with relatives. Most bees don't store large quantities of food in the form of honey. Also, most bees are gentle!

More than 4,000 species are native to the U.S. A native bee is simply one that is "from" an area. You've probably seen some native bees, even if you haven't thought about it. Maybe you've seen bumble bees visiting blueberries *(above)* in spring. Or tiny sweat bees *(right)* licking perspiration from your skin in summer. What about carpenter bees, whose females tunnel into soft wood to lay their eggs?

There are also mining bees, leaf-cutter bees, alkali bees, polyester bees and squash bees, just to name a few! All depend on pollen and nectar for survival as larvae and adults. Many of these native bees are more effective pollinators of crops and wild plants on a per-bee basis than honey bees!

The number of honey bee colonies and beekeepers has been declining in the U.S. for several decades. The great news is wild native bees can do all the pollinating needed if given a chance!

But they need our help. Native bees need these three things to survive:

1. Something in bloom from early spring into autumn. Native bees do best when they always have native flowers to visit.
2. Nesting habitat. Most native bees nest in the soil, so leaving bare patches in sunny spots is key. Other native bees nest in stems and twigs. Leaving forested areas intact also helps.
3. Protection from pesticides. The chemicals used to kill crop pests kill also native pollinating bees! Finding ways to apply pesticides so they won't harm bees can boost their numbers. Eliminating pesticide use is even better.

Visit www.pollinators.info to learn more about native bees and other pollinators, and to join the Pollinator Conservation Movement!

#2- Arizona Federation of Garden Clubs' Greenleaf Bulletin, September, 2011

Ready, Set, Grow

You've probably heard about Colony Collapse Disorder and honey bee declines. But did you know that honey bees are only one of thousands of animals that pollinate plants all over the world? That's right! There are other bees, beetles, wasps, flies, birds, bats and even geckos that are important for plant reproduction. Without pollinators, almost all of the vitamin-rich fruits and vegetables that make our diets more healthy and enjoyable would cease to exist! Pollinators also keep many wild plants reproducing, helping to maintain healthy ecosystems, no matter where they are. Curious yet? Want to know what you can do to help conserve these fascinating and important animals? Check out the new blog www.pollinators.info for more information! The blog is written by pollination ecologist and doctoral student Athena Rayne Anderson, and is user-friendly for all knowledge levels. Stop by the blog and ask questions, leave comments on posts and pages, and spread the word about the importance of pollinators by sporting a pollinators.info shirt or bumper sticker! Pollinators.info is your one stop for pollinator-related information, resources and community interaction!

#3- Kentucky Society of Natural History's Kentucky Naturalist News, Summer 2011

The Importance of Bees

The Importance of Insect Pollination

The importance of insects, especially bees, could not be more obvious than when considered in the context of global food supply. Gordon Allen-Wardell and colleagues stated in a 1998 article in the journal *Conservation Biology* that "the management and protection of wild pollinators is an issue of paramount importance to our food supply system." The authors reported that many crop failures worldwide in the last several decades resulted from scarcity of wild pollinators. California almond orchards suffered a decline in 1995 due to weather and pollinator loss. The cashew nut crop harvest in north Borneo is consistently suboptimal because the species is native to Brazil and has no native pollinator in the Old World tropics. Unfortunately, the possible effects of pollinator declines on the human food supply are critically under-studied.

Until 1990 it was believed that only a handful of plants feed the world, but a paper published that year in *Conservation Biology* by Robert and Christine Prescott-Allen demonstrates otherwise. By examining national food supply data the authors discovered that more than 100 plant species provide 90% of the food for 146 countries worldwide. The authors point out that this new information shows the importance of conserving plant species and genetic diversity if we are to safeguard our food supply.

More than 70% of the plants listed by the Prescott-Allens as crucial to feeding the world are pollinated by insects. The authors have also documented 60 crop plants crucial to the North American economy and their level of dependence on insect pollinators. They found that seven crops (cashew, squash, mango, cardamom, cacao, cranberry, and highbush blueberry), worth $1.25 billion per year, are dependent on insect pollination. The importance of insects to food plants is supported by other sources as well. Dave Roubik, a tropical bee researcher, estimates that 800 species of cultivated

plants worldwide require insect pollination. Of these species 19% are pollinated by flies, 5% by wasps, 5% by beetles, 4% by butterflies and moths... and 73% are pollinated by bees alone.

Bees as Pollinators

Bee Natural History-- Several characteristics of bee anatomy and life history make them ideal as pollinators. First, bees have fuzzy bodies with finely- branched hairs that increase the surface area to which pollen can cling. Second, many bee species have specialized segments on their bodies for collecting pollen. For example, some bees have a corbiculum, a modified section on each hind leg, into which they pack pollen. Other bees have specialized hairs on their hind legs or the underside of their abdomens in which they store pollen (called a scopa) . Third, bees obtain nutrition entirely from pollen and nectar in all their life stages, which makes them intimately linked to a flower's sexual cycle. Fourth, bees are members of the Order Hymenoptera, a group estimated to contain one out of every ten animals on the planet. There are 25,000 species of bees currently described worldwide, and some researchers predict that there might be as many as 40,000 species living today. Approximately 3,500 species of solitary bees live in North America alone. Finally, fossils from Petrified Forest National Park in Arizona suggest that bees evolved around 220 million years ago, more than 100 million years before the flowering plants. This indicates that the explosion in flowering plant diversity might have been the result of coevolution between plants and pollinating bees.

Benefits of Bee Pollination-- Many self-fertile plants benefit from cross-pollination by bees. A paper published in 1976 by R.B. Kozin described several crops that benefit from cross-pollination by bees in Russia. Among the plants studied were red clover, long-stemmed flax, and fodder bean, their yields increasing as a result of bee pollination by 400%, 48.8%, and 89%, respectively. Protein content, seed quality, and number of

seed pods per plant also increased with cross-pollination. Increases in fruit and seed yield and quality as a result of bee pollination have also been reported in buckwheat, sunflower, and citrus varieties.

In 2006, Sarah Greenleaf and Claire Kremen found that SunGold tomatoes, a variety previously thought to be primarily self-pollinating, increased fruit yield as a result of bee pollination. In fact, fruit production in this crop decreased when pollinators were prevented from visiting flowers, which indicates that tomato yield could be correlated with bee abundance. Experiments with canola show similar benefits of bee visitation. Of particular interest is the discovery that canola on organic farms produced more seeds than that on conventional or genetically modified farms, most likely due to a healthier pollinator population on the former.

The benefits of bee pollination translate directly into monetary figures. Insect pollination in the UK, mostly by honey bees and bumble bees, is valued yearly at £202 million. In the U.S., bee pollination has been linked to increased fruit size and number in pears, cranberries, and blueberries, with a combined increase in revenue of more than $4,100 per acre. Alfalfa is another important crop benefiting from bee pollination, and alfalfa- derived products accounted for $12 billion per year in 1990. Alfalfa hay feeds most of the livestock in the U.S., and is alone worth $5 billion yearly.

Bees are important as pollinators for more than our agricultural crops. It is estimated that bees pollinate 16% of the world's 250,000 flowering plant species. Given that this total includes water-, wind-, and animal- pollinated plants, the importance of bees is underestimated by this figure. Interestingly, new research has found that not all bees are equal as pollinators. Some bees are extremely efficient pollinators of a small number of plants, while others are moderately efficient at pollinating a variety of plants. Until recently, most pollinator research focused on honey bees and they were thought to

be the primary pollinators when they were present. We are only beginning to understand the importance of other bees as pollinators of our crops and unmanaged plants.

Honey- making Bees

Historical Interactions-- Honey- making bees are those which produce large stores of concentrated nectar in the form of honey as their primary food source. Humankind has been pilfering from honey-making bees for thousands of years. Honey bees figure prominently in the mythology of cultures as diverse as the San people of the Kalahari Desert and societies from ancient Romania, India, and Brazil. Beekeeping was so important to the ancient Egyptians that they used a bee hieroglyph to represent all of Lower Egypt, where honey and wax were major economic products. Egyptian beekeeping was a model for bee management throughout the Mediterranean and influenced the societies of the ancient Greeks and Romans. Langstroth's 1852 invention of the removable hive frame changed European beekeeping from a destructive honey harvest to productive colony management. Beekeeping was economically important throughout Europe for wax, honey, and honey wine (mead). In the Americas, the ancient Mayans maintained hives in a tier of log colonies protected by thatched roofs. They valued their honey-making bees for their sweetener and wax, but also as crop pollinators.

European Honey Bees in North America-- There are no honey-making bees native to North America, a fact which prompted settlers to import the European honey bee, *Apis mellifera*, to the U.S. as early as the 1600s. Gloria DeGrandi-Hoffman stated in a 2003 publication that "The history of beekeeping in the United States is interwoven with the history of U.S. agriculture." Although honey bees were brought to North America for their honey and wax, their value as pollinators has far surpassed their other contributions to our culture. Buchman and Nabhan estimated in 1996 that the monetary

worth of honey bee pollination services is 50 to 60 times greater than anything else gained from their management. One estimate places the value of pollination services from honey bees in the U.S. at $112 billion per year. In 1988 there were approximately 3.4 million managed honey bee hives in the U.S., maintained by hobbyists and professionals combined.

Sources predict that honey bee colony numbers will decline continually due to Colony Collapse Disorder and other pathogens, and it is becoming clear that honey bees can no longer be relied upon as our primary agricultural pollinator. For instance, if native bees cannot be recruited to pollinate alfalfa, a decline in honey bee colonies could result in a 70% loss in alfalfa crops, costing the U.S. about $315 million per year. Taking all crops into account, a failure on our part to boost native pollinator populations to a level that could replace honey bees could result in an annual loss of $5.7 billion. The message is clear: either we conserve and promote the diversity of our native pollinator populations, or our culture will be faced with a very expensive and uncertain future.

Pollen Bees

Bees that do not make and store large quantities of honey are known as pollen bees. Unfortunately, the majority of bee research in the last several decades has been devoted to honey bees and we are only recently learning even the basics of pollen bee life history. Although we have identified some pollen bees as highly beneficial for crop pollination, the gaps in our knowledge of this diverse group are astounding.

In the case of some crops, pollen bees are essential for facilitating pollination because honey bees are incapable of doing so. Sometimes both pollen- and honey bees are able to pollinate a crop but research has found that the former is more reliable and efficient. The following sections detail the importance of several pollen bee species to crop production and pertinent management practices.

Bumble Bees-- Bumble bees (genus *Bombus*) are one of the few groups of pollen bees which can be reared and managed with relative ease. These bees have an annual life cycle, with the colony dying before winter and only mated queens hibernating until spring. A wild bumble bee queen selects an abandoned rodent burrow or grass tussock as a nest site and begins a colony that could eventually contain several hundred members. The workers store small amounts of honey in tiny pots for use in inclement weather, but must obtain pollen and nectar almost daily to survive. Because of this, they are often active earlier in the year and in worse weather than honey bees.

Queens can be encouraged to nest in manmade structures such as overturned garden flower pots or nest boxes designed for commercial purposes. They are relatively easy to manage, since their hibernation can be interrupted and colony establishment can be induced to coincide with crop flowering year-round. In contrast to honey bees, bumble bees have long tongues that make them better pollinators of flowers with long corollas, such as broad bean and red clover.

Bumble bees' large size makes them more effective pollinators of some crops like alfalfa which must be weight-activated to expose their sexual structures. They are one of only a few bee groups capable of buzz pollination (sonication), in which a flower's anthers are vibrated at a certain frequency to release pollen. Plants in the nightshade family, such as tomatoes, require sonication and bumble bees are essential to fruit and seed set in these crops. According to a publication by Lane Greer in 1999, bumble bees are the only potato pollinators in the world. Unlike honey bees, bumble bees are incapable of recruiting their sisters to flowers, and are therefore more faithful to the crops for which they are managed.

Alkali Bees-- This species, *Nomia melanderi*, nests in moist alkaline soils, hence its common name. Although they are solitary, their nests may be found in congregations of thousands where habitat is suitable. In the 1950s farmers learned that they could

attract these valuable pollinators by creating appropriate nest sites, and alkali bees remain one of the few solitary species which have been commercially managed. As reported by Buchmann and Nabhan in 1996, alkali bees were essential to alfalfa production in the U.S. for several decades. Alfalfa seed alone was worth $115 million in 1990 and the contributions of this crop to the American economy have already been highlighted.

Unfortunately, the importance of alkali bees to alfalfa yield was not realized until it was possibly too late to maintain their populations at a sustainable level. In the 1940s demand for alfalfa seed led farmers to plow more of their land, including alkaline soils where bees were nesting. In the 1950s and '60s pesticides which are toxic to alkali bees were used on alfalfa to control pest insects. Alkali bees are also vulnerable to heavy summer rains, which coincide with their nesting times, and their numbers suffered as a result of this as well. These combined factors killed many of the wild alkali bees in Washington state, and led to a loss in alfalfa revenue of $275,000 in 1973. Alkali bees also suffer from competition between honey bees and alfalfa leaf-cutting bees (described below), which has contributed to their population declines in recent decades.

Alfalfa Leaf-cutting Bees-- The alfalfa leafcutting bee, *Megachile rotundata*, was unintentionally introduced to the U.S. from Asia in the late 1930s and is now one of our primary alfalfa pollinators. They have also been found to benefit seed formation in many clover varieties in North America. Rather than nesting in soil like alkali bees, leaf-cutting bees nest in pre-existing holes in wood or stems. Their common name is derived from the female bees' habit of removing circular leaf sections with which to line their brood cells. Leaf-cutting bees have proven more manageable as pollinators than alkali bees because they tolerate a broader range of habitats and readily accept artificial nest sites.

Squash Bees-- Bees in the genera *Peponapis* and *Xenoglossa* feed almost exclusively on nectar and pollen from plants in the family Cucurbitaceae, namely

squash, gourds, pumpkins, and cucumbers. They are soil-nesters with an annual life cycle similar to other pollen bees. These bees are extremely effective pollinators of cucurbits and have been found to be more beneficial to these crops than honey bees. A study in Mexico found that it would take 3.3 honey bee visits to facilitate full seed formation in gourds, but only 1.3 visits by a squash bee female. Squash bees are often observed resting, sleeping, and mating inside squash blossoms, pollinating the flowers in the process.

Orchard Mason Bees-- Bees in the genus *Osmia* are called “masons” because they line their nests with mud or pebbles. Orchard mason bees are also named because they are excellent pollinators of orchard crops such as apples and pears, and they show great potential as blueberry pollinators. These bees are solitary but gregarious, preferring to nest near conspecifics. Females build nests in stems or wood, and readily accept manmade nest sites. Research has found that, like squash bees, orchard mason bees are more effective pollinators on their choice plants than honey bees. Despite these characteristics, orchard mason bee management is not practiced on a large commercial scale. However, recent studies report that successful management of blue orchard bees is increasing, making this species one of a few pollen bees to be commercially maintained.

Challenges and Conclusions

The species described above represent only some of North America’s commercially valuable pollen bees. As already discussed, these and other bees are declining worldwide, endangering the stability of global biodiversity and our food supply. Bee diversity is very low in agriculturally- intense European countries and plant-pollinator communities as a whole are failing in these areas. Research shows that specialist bees, those that only feed on pollen from a certain group of plants, have lower genetic diversity

than generalist bees, putting them and their host plants at greater extinction risk. One possible reason for global bee decline is a loss of plant diversity resulting from habitat destruction and intensive agricultural practices. Buchmann and Nabhan reported in The Forgotten Pollinators that 65% of 258 plant species show incomplete fruit set from lack of pollinator visits. Several authors cite lack of basic natural history and taxonomic information as a major obstacle in conserving global bee fauna.

We are in the midst of a crisis of alarming scale. In an effort to halt the demise of our most valuable pollinators, researchers are attempting to elucidate ways in which to bolster bee populations. All bees have three basic requirements: nest sites, food, and protection from pesticides. These requirements are species-specific, and must be considered when determining a conservation plan. Bees such as the orchard mason will nest in a variety of conditions, whereas others are very particular. All bees require season-long food plants as well. Several sources have found that allowing agricultural field margins to persist and providing fallow fields near crops will benefit pollen bees. Planting wildflower seed mixtures that bloom when target crops are inactive have proven highly beneficial in maintaining many pollen bee species. Some studies have found that diverse flower mixtures attract the most bees, but that care should be taken to tailor flower mixtures to bee species of interest, as not all bees respond similarly to flower diversity and density.

Studies have also found that proximity to natural areas positively affects bee diversity. Organic farming practices are also beneficial for bees and other pollinators. Organic farms near natural habitats maintain the highest bee diversity, and can have enough native pollinators to provide all necessary pollination. Connectivity of natural habitats can also be important to maintaining pollinator populations, as can increasing diversity of habitats bordering farmlands. Unused land sections, such as power line

rights-of-way and highway medians can be extremely valuable for conserving native pollinators.

APPENDIX E- VISITOR INTERACTIONS

Visitor- Author Dialog

1. In reference to the post, “Pollinator Profile: Bee-flies.” Initiated August 2, 2011.
    - **Visitor**: “Hmmm . . . The sexual differences on pollen feeding are not as black and white as that. In general females consume more pollen than males. Sex related diet specificity in Bombylius major: http://www.springerlink.com/content/k63428qt53g00... The same is true of other families such as syrphid flies. It is because females need protein for egg production. I have seen male and female syrphid flies slurping nectar and I suspect that both sexes of bee flies use their long proboscis to drink nectar, although I would like to find a reference.”
    - **Author**: “Hi... Thanks so much for the comment! The reference I used for the info about female adults was a 1999 publication, the World Catalog of Bee Flies (http://hbs.bishopmuseum.org/bombcat/introduction.pdf)," target="_blank"> (http://hbs.bishopmuseum.org/bombcat/introduction.pdf), and it reads that females are obligate pollen feeders. I thought that sounded a little odd, but I'm trying to go with the published research! Maybe we've learned more about the topic in the 12 years since the catalog was published...? Thanks also for the article link!”

2. This discussion started with a visitor’s answer to one of my questions in the post, “What have you done for them lately?” Initiated August 7, 2011.

- **Visitor**: “I have a small garden with native wildflowers that provides something for pollinators throughout the growing season. I also minimize my use of pesticides and herbicides. I also talk to people about my garden. A neighborhood child was afraid of the bees in my garden. I explained that the bees weren't interested in us. So as long as we left them alone, we didn't need to worry about them. Anyway, I found your site Googling on squash bees. I took a picture of one this morning, and it looks like there is a drop of liquid between its eyes: http://amyhunter.net/ctm/2011%2008%2007_Garden_00... I'm curious what the drop might be--nectar? water? Why would the bee have it there--is it carrying it someplace? I can't imagine it's not intentional. It was using a foot to wipe an eye while I was photographing it, but it doesn't seem to have been trying to dislodge the drop. I'm fascinated, but can't find anything on Google. Thanks if you have any info!”
- **Author**: “Hi...Thanks for sharing your story! Your photo is fantastic! I'm not sure what you're referring to as a drop of liquid on the bee's face. The yellow patch in the lower center of this bee's face is part of his exoskeleton. All male squash bees in the genus *Peponapis* have this mark. It's also raised in a sort of bump, which is also typical of these little guys. I think it makes the especially cute. Let me know if you were referring to something different and I'll try to help figure out what it is!”
- **Visitor**: “Oh! You know, I think I see the yellow mark. It's the lemon yellow patch right in front of his antennae, right? Since I don't know what I'm looking at (have never seen a squash bee before, let alone this magnified), that lemon yellow area looked like reflected highlights from the squash. That gave me the impression that the "bump" was a sphere of liquid. Especially since

the darker areas around the edges looked like shadowing. Thanks for the response...that's really interesting! I'm planning to put this picture (along with a couple of others from my garden) up on my website. Probably in 2 or 3 weeks. I'll link back to this thread when I do that so folks know where I learned about what you can see in the picture. Your site is really interesting."

- **Author**: I'm glad I could help! Yellow markings on the "face" are actually pretty common in male bees. Sometimes male bees have fuzz on their faces that females don't have. And, there are cases where both male and female bees have yellow on their faces! Just another neat thing about bees!

3. In response to the post, "How many species of pollinator are managed for agriculture?" Initiated August 22, 2011.
    - **Visitor**: "Bees may not be the only managed crop pollinators. Flies are used for pollination of carrot seed crops. They are caged in with the carrot plants."
    - **Author**: "Hi... and thanks for the comment! I had no idea flies were caged to pollinate carrots- this is great! What kind of flies are used?
    - **Visitor**: "Yeah, I was surprised when I discovered that, especially since most books and other sources of information discuss the use of honey bees! I don't know if there is a preferred species of fly, but they are muscids."

4. In response to the post, "Pollinator Profile: Spiny Mice." Initiated on February 5, 2012.
    - **Visitor**: "Hi! When I was in a rat & mouse club up North (New Jersey), I used to have them as pets and used to breed them. They were extremely cute, but if you didn't\'t tame them when young, they would revert to a \"wild\" mouse

temperament, and boy, could they bite! These mice would actually exercise on those wheels for hamsters! Interesting creatures to keep."

- **Author**: "Thanks for sharing your story...! I've read that spiny mice are popular pets. What species did you breed? I'm hoping to someday see them in the wild, doing their pollination thing! :)"
- **Visitor**: "Hi Athena, I believe they were Egyptian Spiny Mice. They were agouti in coloration."
- **Author**: "Interesting... during my research for the post, I read that more than one species of spiny mice are bred for pets. But they're all called "Egyptian spiny mice." Weird, huh? There is a species native to Egypt, but there are others from all over Africa and the Middle East."
- **Visitor**: "The Egyptian Spiny Mice that we had looked just like the photo above of the Cairo Spiny Mice, except, like I said in my last post, they were agouti in color. I really didn't\'t know about the other species at the time. It really is interesting what animals, etc. are actual pollinators in the world. That\'s why I like your site. Shows the many different pollinators all over!"
- **Author**: "Aren't pollinators fascinating?! That's why I started the blog, so it makes me really happy to hear that you're enjoying it for the same reason! :)"

Visitor Comments

- "I know little to nothing about native bees. Now I know where to come when I'm ready to learn more. Thanks for the book information Athena. I'm off to see how much the ebook version costs."

- “content is well-written and accessible” (In response to survey question, “What do you like most about the site?”)
- “Great resource for educators!”
- “Information is accurate and wide ranging” (In response to survey question, “If you are a subscriber, please tell me what motivated you to subscribe.”)
- “Interesting information and well-written articles” (In response to survey question, “If you are a subscriber, please tell me what motivated you to subscribe.”)
- “I created a Pollinator garden (specific to Honeybees) last spring and while doing research for plants I ran across your site. Very helpful, informative and fun!” (In response to survey question, “If you are a subscriber, please tell me what motivated you to subscribe.”)
- I am working on a Masters degree in Education and will be getting certification to teach High School Biology. For class I had to make a 13 session lesson plan and built it around Plants and Pollinators. I came across your site while hunting the web for relevant resource material. Thank you for your efforts!” !” (In response to survey question, “If you are a subscriber, please tell me what motivated you to subscribe.”)

APPENDIX F- SITE VISITOR COUNTRIES

1. Algeria
2. Anguilla
3. Antigua and Barbuda
4. Argentina
5. Aruba
6. Australia
7. Austria
8. Azerbaijan
9. Bangladesh
10. Barbados
11. Belarus
12. Belgium
13. Belize
14. Bermuda
15. Bolivia
16. Boznia and Herzegovina
17. Brazil
18. Brunei
19. Bulgaria
20. Cambodia
21. Cameroon
22. Canada
23. Chile
24. China
25. Colombia
26. Costa Rica
27. Croatia
28. Czech Republic
29. Denmark
30. Dominica
31. Ecuador
32. Egypt
33. El Salvador
34. Estonia
35. Ethiopia
36. Finland
37. France
38. French Guiana
39. Georgia
40. Germany
41. Ghana
42. Greece
43. Guam
44. Guatemala
45. Guyana
46. Hong Kong
47. Hungary
48. Iceland
49. India
50. Indonesia
51. Iran
52. Iraq
53. Ireland
54. Isle of Man
55. Israel
56. Italy
57. Jamaica
58. Japan
59. Jersey
60. Jordan
61. Kazakhstan

62. Kenya
63. Kuwait
64. Laos
65. Latvia
66. Lebanon
67. Libya
68. Lithuania
69. Luxembourg
70. Macau
71. Macedonia
72. Malaysia
73. Maldives
74. Mauritius
75. Mexico
76. Mongolia
77. Morocco
78. Myanmar
79. Namibia
80. Nepal
81. Netherlands
82. New Zealand
83. Nicaragua
84. Nigeria
85. Norway
86. Oman
87. Pakistan
88. Panama
89. Paraguay
90. Peru
91. Philippines
92. Poland
93. Portugal
94. Puerto Rico
95. Qatar
96. Réunion
97. Romania
98. Russia
99. Rwanda
100. Saint Vincent and the Grenadines
101. Saudi Arabia
102. Serbia
103. Singapore
104. Slovakia
105. Slovenia
106. Solomon Islands
107. South Africa
108. South Korea
109. Spain
110. Sri Lanka
111. Sudan
112. Sweden
113. Switzerland
114. Syria
115. Taiwan
116. Tanzania
117. Thailand
118. Trinidad and Tobago
119. Tunisia
120. Turkey
121. Uganda
122. UK
123. Ukraine
124. United Arab Emirates
125. Uruguay
126. US
127. Uzbekistan
128. Venezuela
129. Vietnam
130. Virgin Islands
131. Zambia

APPENDIX G- PODCASTS

Podcast Episode 1: Interview with Dr. Stephen Buchmann

Quick Glossary of science terms that aren't explained in this podcast:

1. Pollinator: an animal that makes pollination happen.
2. Pollination: transfer of pollen from the anther to the receptive female organ of a flower (the stigma).
3. Anthers: parts of a flower that hold pollen.
4. Pollen: sperm-transport vessel for a flowering plant.
5. Stimuli: things that make (stimulate) something (to) happen. For instance, tasty-smelling food is one stimulus that can make your mouth water.
6. Flight room: an enclosed area in which flying animals are allowed to fly around.
7. Foraging: looking for food.
8. Quantifying: counting some aspect of a thing. For instance, counting the number of times a bee buzzes when it lands on a flower.
9. Macro camcorder: this is a video camera for making videos of tiny things.
10. Thermally: in relation to temperature. For instance, I don't like being cold, so 30^{o}F is not the right climate for me thermally.
11. Chemical assay: a particular type of chemical test. For instance, a chemical test that measures the amount of protein in pollen is called a "crude protein" test.
12. Mutualism: a relationship in which both parties benefit.
13. Stone fruits: the ones with a really hard "pit" in the center, like peaches, nectarines, and cherries.

Athena (ARA): Hi there, thanks for joining us today; this is pollinators.info podcast episode 1. I'm Athena Rayne Anderson, the author of pollinators.info. It's July 20th, 2011, and today I'll be interviewing Dr. Stephen Buchmann, co-author of The Forgotten Pollinators and several other books, he's the International Coordinator of NAPPC, the North American **Pollinator** Protection Campaign, and he's also an adjunct faculty member at the University of Arizona in Tucson. Today I'm going to be talking with Dr. Buchmann about buzz pollination, or sonication.

Can you give the listeners a description of what that means?

Dr. Stephen Buchmann (SB): Sure. Buzz **pollination** is really amazing. It's something that I've been working on, off and on, since high school, actually. It's just fired up my imagination. If you look at the flowers of a tomato, eggplant, blueberry, or cranberry, those are typical crops that need to be buzz pollinated, and it really means that the **anthers**, instead of having loose pollen all over them, have little holes in the tips of the anthers and that is really the only way the pollen can get out of the flowers. So, bees literally turn themselves into living tuning forks; things like bumble bees. Honey bees, for some weird reason, can't buzz flowers like that. But anyway, bees like bumble bees will land on the flower, bite into it, and sonicate, or buzz the pollen out of the flower. And it happens very quickly; it can happen in just a few tenths of a second. And it makes kind of a comical noise, the buzzing of the bees on the flower, so I just tended to call it buzz pollination. It is a very efficient type of pollination so that bumble bees using the buzzing on tomatoes, or blueberries, cranberries, a number of plants... kiwi fruit, actually, in New Zealand, can vibrate the pollen out about 400 times faster than a honey bee can [get the pollen] just kind of scrabbling around in the flowers. It's pretty neat. It turns out that about 8% of the world's flowering plants have those funny little holes, those pores, in their anthers, and have some kind of bee that comes along and vibrates them to get the pollen out.

ARA: Ok, did you say 8% of flowering plants?

SB: Yeah.

ARA: Ok, so you already mentioned that bumble bees can buzz pollinate, and that honey bees don't. Are there other bees that are good at it?

SB: Yeah, there are bees in the sweat bee family, the Halictids, so, brilliant metallic green bees like [the genus] *Agapostemon* and others, that will go to tomato blossoms and that sort of thing. Then we have the giant black carpenter bees, which occur over much of the United States, we have quite a few of those in Arizona, and they are really adept at the buzzing, so they're great at buzz pollination too. So, a fair number of bees do it. There are some exceptions; the leafcutter bee family, we don't really know of anything in that family that does it. And honey bees. So, those are the two main exceptions.

ARA: Ok, so what are you currently involved in dealing with buzz pollination?

SB: Yeah. What we're doing with buzz pollination, I'm actually working with Dr. Stan Pappage and [Dr.] Annie Leonard, one of his postdocs at the University of Arizona in the Ecology and Evolutionary Biology Department. So, we're using real flowers and artificial flowers, you might think of them as sort of robotic flowers, to kind of tease out what are the **stimuli** that make the bees buzz. So what is it about a flower that will make one of these bees [buzz], and we're working with bumble bees- commercially available colonies of a bumble bee called *Bombus impatiens*. And so we have these in a laboratory and in the **flight room** we're presenting the bees with different combinations of flowers and different shapes and just trying to figure out what is it about certain flowers that indicates to the bees that, "Hey, this is a flower you need to do this fancy buzzing on."?

ARA: Do you have any results for that yet?

SB: Not too much, we're just starting the study. We're at least getting bees to visit our artificial flowers, which are kind of interesting, and we designed some artificial anthers so we're changing colors and size and shapes of those to see what difference it makes on the bumble bee **foraging** behavior.

ARA: Ok, and what are some particular challenges that are involved with this work?

SB: Mainly **quantifying** the behavior, so we're actually using a little **macro camcorder** so when the bees land on the flowers, whether they're the real flowers or the modified artificial flowers, we videotape them and then we have a little tiny microphone mounted nearby. So if they do vibrate the flowers, we can actually hear the buzzes that the bees make, and we can quantify them and count the number of buzzes, the duration, the frequency of the vibration, that sort of thing. So, that's the biggest challenge: really trying to quantify and see exactly what's happening.

ARA: What has been your favorite part of this work, or what's been the most rewarding part of it?

SB: Just working at it officially. I hadn't worked on buzz pollination for 4 or 5 years, so it's kind of nice to get back into it and to be able to work with it in a controlled situation. Sometimes the vagaries of working in the field can be pretty challenging and really exasperating, so it's nice to be able to control the stimuli that we're giving the bees and do it in the setting in the laboratory. So, I think that's been the most fun so far.

ARA: Yeah. What are some broader impacts and how this research, and buzz pollination research and understanding in particular, can benefit the public?

SB: I think just making the fact known that the blueberries, cranberries, eggplant, kiwi, tomatoes, some peppers... that some of these important crops, like tomatoes, are dependent upon bees for fruit set. For example, the world's largest greenhouse is located about three hours from my house, near Wilcox, Arizona, Bonita Nurseries, and

they have almost 400 acres of glass greenhouses. They grow 1/6 of all the TOV, tomatoes on the vine, for the United States. So it's a huge, huge, you know, billion dollar operation, and people are not running around in there with little tuning forks. I mean, they buy bumble bees, and bumble bees are pollinating the crop, so they're essential to the crop. Just like many of these crops, tomatoes, peppers, and eggplants that the home gardener might grow in their yard are dependent upon bees that they don't know exist, or that people don't observe. A lot of times this buzz pollination happens really early in the morning, right around sunrise. So a lot of people might get up at, you know, 8 o'clock and have a cup of coffee and walk out into their garden at 9 or 10 o'clock and they don't see any activity because, well, it was happening five hours earlier.

ARA: Aah. Do you know of any research explaining why they do it so early?

SB: No, not really. A lot of these bees, especially bees in the desert southwest just start foraging really early in the morning. I mean, it may have something to do with it just being too hot later and maybe not right **thermally**. Also, there's probably also an advantage to being some of the first bees to hit the flowers that are full of pollen. A lot of these flowers, like tomato blossoms, do not contain any nectar; they're pollen only. But the pollen is a super-rich food. I did some chemistry on it years ago and I found that protein content of average pollen from a typical [non-buzz pollinated] flower would be 20 or 30% crude protein, and yet I found some of these wild deadly nightshades in the genus *Solanum* and then also *Licopersicum*, the tomato genus, had wildly high values of crude protein- up to 60, six-zero, percent protein in the pollen.

ARA: So, the crude protein is better for bees than another kind of protein?

SB: No, the crude protein is just a **chemical assay**, but a higher protein value is better, so the fact that most flowers are producing only 20 or 30% protein, and the pollen from almost all of these buzz [pollinated] flowers that I've looked at is 40, 50, even 60% just makes them a super-nutritious resource for the bees.

ARA: Ok, so the last question is, as a pollinator researcher, what would you recommend for people who want to help pollinators? What are one or two things that they could do in their lives or on their property that would be beneficial?

SB: Sure. First thing I would say is actually, may sound kind of funny, but don't be so neat and don't chop everything down. For example, standing dead trees or even a dead branch in a tree is important to leave because there's an intense partnership, almost a **mutualism**, between beetles and bees. And so, when wood-boring beetles, especially in the families Buprestidae and Cerambycidae, when their larvae tunnel out of the wood and they become adults, they leave those tunnels, those galleries, behind. And 10 or 20%, at least, of the native bees in an area are what we call leafcutter or mason bees, which tend to be excellent crop pollinators, especially of different **stone fruits** and sweet cherries, lots of fruit trees, those mason bees and leafcutter bees can't dig their own nests in wood. So, they rely on finding a pre-existing cavity or hole. So female leafcutter bees and mason bees move into those holes based on the size; they select them and then that becomes their nest. So it's really important to leave the odd dead branch or, if you have a large property, a dead tree, because it's not just important habitat for pollinators, but also for other wildlife [like] lizards and birds. So that's one thing.

The next thing I would suggest to people is to use as many native plants as possible, native to their local area or region, because they are adapted to the local pollinators and they don't require huge inputs of fertilizer and water. They can pretty much take care of themselves and they're used to the local soil and climate conditions. So by using either native plants or older heirloom varieties, you get away from utilization or dependency upon hybrids. And if you go to nurseries and buy hybrid flowers, a lot of times these have been selected by plant breeders for human sensibilities, not for the pollinators. So a lot of times they don't have enough nectar or pollen, or sometimes not

even any of those things, to support bees and other pollinators. So that's important to do.

People should also plant in clumps, not just one plant, but 4, 5, 6 of the same kind of plant in a clump because those are more attractive to pollinators.

They should make sure that they have plants that bloom throughout the year, spring, summer, and into the fall, because it's really important for certain bees, especially things like honey bees, bumble bees, and carpenter bees, which have very long-lived associations, that they need nectar and pollen throughout the year. So you can bring pollinators into your yard and garden by having a diverse... having diverse flowering plants and making sure that things are coming on when other things are going out of bloom. So, kind of a steady bloom through the year is best if you can manage it.

ARA: Ok, so leaving branches on your property, planting natives, uh, planting in clumps...

SB: Yeah... gardeners need to be mindful that 90% of the bees in the world are ground-nesting, so they require compact, open, sunny spaces to nest. So if you go around and mulch everything with black plastic, or redwood bark, or under concrete paths, you're destroying nesting and living habitat for native bees. So you need to have kind of a light hand with mulching and that sort of thing.

ARA: Right, so be friendly to the messy spaces, basically?

SB: Yep.

ARA: Alright, well thank you so much, Dr. Buchmann, for joining us.

SB: Sure!

ARA: Once again, thanks for joining me. My name's Athena, I'm the author of pollinators.info. If you'd like to be a member of the Pollinator Conservation Movement, just go to www.pollinators.info and click on "Subscribe Here" and enter your information,

and you'll get a free weekly email newsletter and some occasional other updates and notices of when you can look forward to other future podcasts. Thanks again, take care.

Podcast Episode 2: Interview with Sam Droege

Athena (ARA): Hi there, thanks for joining me today; this is pollinators.info podcast episode 2. My name's Athena, I'm the author of pollinators.info, and today we'll be talking with Sam Droege, who works with the US Geological Survey, about bee and wasp surveys in Guantanamo Bay, Cuba.

Well, thanks for joining us today!

Sam Droege (SD): Sure.

ARA: Can you start out by telling us: what is your official job title?

SD: I'm a biologist with the US Geological Survey and right now I'm running the North American native bee inventory and monitoring lab.

ARA: Ok, so you're doing bee surveys at Guantanamo Bay. So, can you give us a description of that project?

SD: Yeah. Guantanamo Bay is the naval base, something like 36 square miles on the southeastern portion of Cuba. Their environmental groups are encouraging scientists to come down and do core surveys for different groups of animals, and until we had been there they had, for example, no large-scale animalogical surveys being done. So the immediate goal is to do an inventory of the bees and wasps of Guantanamo Bay. To put that in the context of the larger picture is that because there is very limited access to the rest of Cuba, this becomes our one place that we can look at Cuban bees relatively easily, even though it is on a military base. At this point, we've found over 30% of the bees that are known to have occurred on Cuba and the reason this is important is just knowing something about the bees, and knowing about the habitats that occur on the base and how important the base might be, the habitats it contains, for the conservation of bees in Cuba. It also allows us to do comparisons with other islands in the Caribbean. And so, other groups are looking at more accessible

islands throughout the Caribbean and we can play the part of adding information about what the bees are like on Cuba.

ARA: Right.

SD: I think I should add onto that that there is a fair amount of historic information, so we do have a way of contrasting the bees we're finding in Guantanamo Bay to what's known elsewhere in Cuba. But it's the only place where we're getting new information.

ARA: Ok, so what does it mean to do a survey for bees and wasps?

SD: We use three different techniques on the base.

1. One is [that] we have little traps, and these are nothing more than colored bowls- blue, yellow, and white- that are filled with soapy water. The bees are attracted to the color; if you think of a bee, when a bee gets up in the morning, the first thing it's looking for is color, because color is a very unusual aspect to the natural environment, not of course the manmade environment. But to the natural environment, anything that's blue or yellow is very novel, and that's why flowers have developed those color schemes; it's because they stand out [and] it attracts bees. And so a bee doesn't necessarily know that a little colored bowl filled with soapy water is not a flower, so it comes over and investigates and lands in the water. And we have further tricked them because the soap gets rid of the surface tension. What would normally happen, bees do this all the time, is they land on top of water to gather water for their nest or just maybe, perhaps, by accident. And wasps do this too, because many wasps come to flowers. So they would be on the surface tension, but the surface tension is gone with soap. And the soap actually kills them too. So,

they land in the bowl, and we then identify the specimens. That's one technique.

2. The other is a traditional one of an entomologist out there with a net, hunting bees on flowers, or looking for nest sites, and catching them in the air. It turns out, in Cuba, that is a relatively difficult thing to do because, first of all, it's often very hot and sweaty. Second, a lot of the habitat in that part of Cuba is cactus and thorn scrub. We're not talking little tiny cactus, either, or cacti. We're talking cactus that are upwards of 25-30 feet tall. So that combination makes the physical landscape a little more difficult than normal [survey locations]. But additionally, the amount of visible bees can be low, so we may only get a few bees for an hour's worth of looking for them, whereas elsewhere we'd be dealing with several hundred.
3. And finally, the last technique is we have these things called Malaise traps which are big, essentially net tents that have a collecting jar at the top of the tent and bees blunder into them and wander into the collecting head and we periodically pick up the bees and we then sort through them later.

ARA: Ok, some people might not know what traditional bee-catching means and why cacti are not good...

SD: Sure. I guess many people would call this a butterfly net. There's a handle, a hoop at the end of that handle and then there's a netting bag and what one does is go out into the environment, mostly looking for flowers. Then you look for bees that might be visiting those flowers, and then you try to intercept those bees with your net. And it sounds pretty easy, but bees are super-fast and they have to avoid a lot of different predators that're trying to catch them to eat them, so if you sort of mosey up to them with

the net, and mostly they're gone by the time your net gets to anywhere near where you thought they were. And, they're moving very quickly too, they're not lounging around on flowers; they're usually zipping. So, it becomes a bit of a skill to be able to quickly net a bee on flowers. And then, on top of that, you have all these thorny plants and because you have this cloth, net bag, it's just netting, the two don't go well together. So, a lot of times you're snagging your net on cactus, snagging it on a big thorn scrub, which are worse than cactus, and ripping your net open. Or, at least, you're having to limit what kind of flowers you can get [bees from] because if you have a lovely flowering thorn tree, it doesn't do any good because you can't swing a net onto the flowers- you have to try and catch them (the bees) coming and going, and that's even more difficult.

ARA: Right. So which one of those three methods do you usually get more bees with?

SD: Oh, certainly the... what we call "bee bowling;" the putting out of these little bowl traps. On each of the trips we put out about 1,000 traps all across the base during that time period. The traps are out only for a day and then we move them to a different place. So, bees, in general, are not out early in the morning and late in the afternoon. So we'll get up at dawn, put out traps all morning long and then we come back in the afternoon, pick up the traps, and then we go to bed.

ARA: (laughs) And then get up and do it again the next morning.

SD: (laughs) We do it over, and over again.

ARA: I was going to ask, how long does it usually take from start to finish of doing one of these bee surveys?

SD: Well, it depends on what you mean by "start to finish." But we're usually there from, or have been there, we've done three trips now, for somewhere between ten days and two weeks. And, you know, there's times when the weather's not good, and there's lots of different areas we want to get to on the base and I'd say people would not

be surprised to hear that there's access issues! Yeah, you can't just go wandering around in these areas as you might on a national park.

ARA: So, how do you decide where you're going to put your bee bowls?

SD: Oh, we do that based, first of all, on experience. [For example] where we have found good numbers of bees in the past. We try and cover all the habitats. So, on the base, you have mangroves along the saltwater areas, you have some sandy areas and beach-like habitat along the ocean side. There's internal fields and disturbed sites where there's been military training or old buildings, or even current barracks, or those sorts of situations. You have several different kinds of native scrub habitats that occur on the base. So each of those areas may have, and does have, a different group of bees that are either nesting in the soils of those or, more importantly, are using different plant species in each of those habitats. The way bees work, in many cases, is that they have preferences for what they feed their young. So, females are mixing pollen and nectar and provisioning a nest of some kind. A lot of times, though, those females are very much specialists for gathering pollen only from one group of plants, maybe a single genus, maybe sometimes even a single species of plant. So, and those plants have their preferences as to what part of the island they occur on, and what part of the base they occur on too. So we really do need to cover as many habitats as possible.

ARA: Right, so people might wonder: if pollinators are declining and we're supposed to be doing something to conserve them, how do we justify killing bees as part of that process?

SD: Ahh, right. So that's an important question. There's a couple of things going on here. One- they're not like birds. So, with birds you can use a pair of binoculars [and] you can be fairly certain of the identification of a bird, based on their characteristics, which you can easily see if they're standing still, or if they're calling or something along those lines. The problem with bees is, in addition to it's very hard to find them, that, even

if we did see them and we didn't catch them, we wouldn't know what they are. We could say, "Well, there was a bee," but which kind of bee would be impossible to say because even the larger bees are often difficult to separate from one another, because there may be three or four species that look about the same. So we have to look at them under the microscope to tell what they are, so that means catching and killing them. Additionally, if we back up, you mentioned that there was a problem with pollinator decline; that's a public perception and a media perception, and not necessarily what's going on on the ground. In a lot of our surveys we're still finding that the native species still exist, and often in very large numbers. So, if you look at what proportion of the bees that we are capturing might be to the total population of bees, it turns out that it's essentially trivial.

ARA: Alright, so did you mention that there were some other agencies involved in the survey?

SD: Yes, so this is a collaborative project between the USGS and the Smithsonian, and in fact the Smithsonian funded the first two visits to Guantanamo Bay. And, of course, we've been doing this in conjunction with the environmental group of the Navy, who is in charge of the animals on the base and their conservation. And then the last trip, actually, I funded myself. I just took vacation time to go because I was so psyched, shall we say I guess, about finishing up the project and we had run out of money at the Smithsonian.

ARA: Oh, bummer.

SD: It's not that big a deal, you know? If you're going to go somewhere for vacation, who wouldn't want to go to a place where you're sweating, it's full of cactus, and it's hard to find bees?

ARA: (laughs) And you need an armed escort...

SD: (laughs) Right!

ARA: Ok, so having talked about that, what would you say has been the most challenging aspect of the project?

SD: Well, actually logistics are very challenging because of the number of areas that are under some kind of security. It's not too difficult; most of those areas you can get permission to go into, it just slows things down. I have had kind of an obscure problem... normally we put out our traps and we'll leave them out overnight and pick them up the next day. And on our first trip we realized that something was eating the traps. Like, something between 25% and 30% of the traps would be completely chewed-up. They seemed to love to chew the bottoms out, for some reason. And it turns out it was these giant rodents called "hutia," which are related to capybaras. And, elsewhere in Cuba they're apparently very uncommon because they taste good, whereas on the base they sort of overrun the place. So right now we can only leave the traps out during the day and have to pick them up before it gets dark.

ARA: (laughing) Well, that's interesting. So there's a giant rodent eating your traps.

SD: Right, which I have not had problems with before... with giant rodents.

ARA: Ok, so what's been your favorite part of the project?

SD: I think the favorite part of my project has just been the novelty of being both on Cuba, on a Caribbean island, and finding these new and unfamiliar species of bees that I don't get to see in North America. There's a number of species that are endemic to Cuba, there are a number that are endemic to the Caribbean. We've ended up finding probably somewhere between two and, maybe four, species of bees that haven't been described [in] science.

ARA: Oh, neat!

SD: And maybe some that are new to Cuba and others that were thought formerly to be rare that we're finding are regionally common on the Cuban isles. So it

makes it much more like an exploration into new territory than, say, birdwatching in the area, which [is because] the birds are fairly well-known, you're not going to find anything new. But with bees, almost anywhere we're going to find new species, and something interesting, and that's indeed been the case here.

ARA: Right. So, you said there are endemic bees in Cuba?

SD: Yes, and the total number of bees known from Cuba are only 90, and that may sound like a fair amount, but, for example in Maryland where I live, we have something close to four hundred and twenty species known. And Maryland's much smaller than Cuba, so that's a little odd; we don't know why, [which is] one of the reasons to study bees on different islands. So, from past work by the Cubans, on their islands, it's known that a fairly high percent of the bees that are known from Cuba are found only on Cuba, so that makes them an endemic species.

ARA: So, do you have any initial results from the survey?

SD: We have worked up the first two trips and we've got, I think the estimated number was, 35 species. So we're over a third of the known bees from Cuba. We're still working out the identification of some, and we're trying to divine whether some of these species that we don't have a name for are found on other islands or are new species. Oh, I should also point out, which I didn't before; we've been talking about bees a lot, [but] we also have been catching any wasps that have been in the area. From those preliminary results we have, we know there's at least two new species involved and there could be more. So, it'll be the bees and wasps of [Guantanamo Bay] Cuba, and we're all very pleased with the catch we've gotten so far. Far richer than we first suspected. We thought, because that part of Cuba is the driest portion of the island, the average rainfall is only something like 19 inches, and wasn't very well-known, [that we wouldn't find many bees]. And, additionally, we were surprised because it was considered to be just a small pocket of unusual habitat. We were surprised by how many

of the other species on the rest of the island we were finding there. We didn't expect to have, say, somewhere between a third and half of the species of Cuba show up in this region. So, that has also been very interesting.

ARA: Yeah, ok! What would be some broader implications from the work for the general public?

SD: Well,

- one of the things that we will be doing is we're establishing a baseline, so we can look at changes over time. There is this notion that pollinators are declining, or could decline, so we're establishing this as something that could be repeated in the future. Then you can look at whether things changed on the base or not.
- We're doing some very basic science things. So, we're adding some new species to the list [of species known to science], [and] we're getting a feel for how things work on islands. Other collaborators from other parts of the Caribbean are interested in these bees that we have so they can compare to Jamaica, to Hispaniola, to Puerto Rico, some of the other islands in the region.
- For bees, you can add an economic angle, which is that if you don't have bees, some of these plants that occur on the base, or even that are crops in nearby Cuba, are not going to get pollinated. So, knowing at least a little bit [of] something about that gives us some perspective on what's available to act as crop pollinators.

ARA: Right. So, as a final take-home message for the public, what would you recommend for people to do in their lives, or their communities, or their gardens, to conserve bees and wasps and other pollinators?

SD: Right. Well, the one thing that I can tell people that they can do [is] to plant and encourage native plants on your property. Doesn't have to be a lot; instead of planting zinnias and geraniums and begonias, planting [native] things like sunflowers and coreopsis and some of the native hollies and that sort of thing. Those provide both the habitat and the food, the pollen and nectar, that are important to bees. And it encourages wildlife in a stronger community of plants and animals, and it's something that YOU can do. So, every yard has bees in it, but a lot of times they're just making do with feeding off of a few dandelions or weeds, rather than the things that we plant. We make choices based on color, but a lot of the commonly-planted plants you might buy at a big box store are essentially devoid of pollen and nectar because they've been bred too much for color and presentation and disease resistance, and have lost their pollen and nectar on the way because they're propagated artificially.

ARA: So, native plants for native pollinators. Well, thank you so much for your time, Sam.

SD: You bet, Athena.

ARA: Once again, that was Sam Droege with the US Geological Survey talking with us here at pollinators.info about a native bee and wasp survey that they're doing in Guantanamo Bay in Cuba. You've been listening to pollinators.info podcast episode 2, my name's Athena, thanks so much for joining us, take care, and I'll see you next time.

Podcast Episode 3: Interview with Dr. Nathan Muchhala

Quick Glossary of science terms that aren't explained in this podcast:

- Neotropics: tropical region in Central and South America
- Corolla: shape of flower formed from petal fusion. For example, a wild rose has an open corolla, while trumpet creeper has a tube-shaped corolla.
- Kapok tree: *Ceiba pentandra*, a tropical tree in the family Malvaceae (along with cotton and okra), that is a source of clothing fiber and oil in South America and Africa.

Athena (ARA): Hi there! Thanks for joining me today! I'm Athena, the author of pollinators.info, and you're listening to podcast episode 3. This is an interview with Dr. Nathan Muchhala, who studies pollinating bats in the **neotropics**, and he's going to be telling us about the tube-lipped nectar bat and coevolution with the plants that it pollinates.

Thank you so much for joining us today!

Dr. Muchhala (NM): Sure.

ARA: How would you describe your job, or your position?

NM: Well, right now I'm a postdoctoral researcher at the University of Nebraska. So, this is temporary, after getting my Ph.D., before hopefully getting a professor position somewhere.

ARA: How would you briefly describe your current research on this tube-lipped nectar bat?

NM: I'm looking at coevolution between it and the flowers it visits. So, I looked at different habitats throughout its range and looked at what flowers it was visiting and did some experiments as to how or why the flower and the bat might be coevolving together.

ARA: Could you explain coevolution really quick, for people that might not be familiar with that term?

NM: Sure. Coevolution is just a form of evolution. Evolution is where some organism changes in a trait. So, coevolution just means that two organisms are affecting each other and affecting each other's evolution in parallel. Pollinators and flowers are often a classic example of coevolution, and what I'm looking at is the length of the flowers and the length of the bat's tongue; how the two of those coevolved together.

ARA: And, so how long are the flowers and the bat's tongue?

NM: The bat's tongue I measured, on average, is 8.5 cm. The flowers are pretty similar, about up to, like 9 cm deep.

ARA: So what are the flowers that the bat's pollinating?

NM: This particular one, it doesn't have a common name, it's called *Centropogon nigricans*. This [is] one species that I've worked a lot with that has really long flowers. And, they're different- they're not your typical flowers. They basically look like a long, green tube. And they open at night, they produce a really strong odor to attract the bats, and they make a lot of nectar, which is what the bats are interested in.

ARA: Right, so what kind of plant is this? Is it like an orchid, or a bromeliad...?

NM: It's a bellflower, [in] the family Campanulaceae.

ARA: Ok, and so where does your research take place?

NM: In Ecuador, that's where I most have worked. Ecuador, South America. And the bat, we discovered it in 2005, and described it as a new species then, and since then they've been finding it in other countries. They actually just found it all the way south in Bolivia, which is pretty far away.

ARA: Ok...

NM: And in Colombia, so it has a fairly wide range.

ARA: So, can you describe the bat a little bit for people, like how big is it, and what color it is...?

NM: Sure. Nectar bats tend to be very small- they're about the size of your fist. The body length is about 6 cm. And, let's see- they only occur in the southwest of the United States. But, they're most common in tropical habitats. And, they're basically mammal versions of hummingbirds- furry versions of hummingbirds. They can hover in place, and they have elongated snouts- longer than normal bats- and they can extend their tongues pretty far outside of their mouth.

ARA: What color are they? What would they look like to someone who saw one for the first time?

NM: They're brown. They're kind of a typical mammal brown color.

ARA: A little brown bat.

NM: Yep. Brown and furry.

ARA: Ok. Can you tell us a little about the bat's life history, like how long does it live...?

NM: Sure. Bats, in general, tend to live longer than you would expect for something that's that small. Mice, for example, just live a few years. Bats tend to live about 15 or 20 years.

ARA: Oh! That is longer than I would have thought!

NM: Yeah.

ARA: So, the nectar bats are obviously getting carbohydrates from the nectar. Do they ever eat insects for protein? Or, where do they get protein? Do they eat some of the pollen?

NM: They eat pollen. That's a pretty important source. I don't think they actually go to flowers and eat anthers directly like, to try and get pollen directly, but they groom their fur...

ARA: Oh! Ok...

NM: And they get a lot of proteins from pollen. And, some of them eat insects too. I've been working for a while with trying to figure out what they're eating based on the feces of bats, and always find insect parts in them. It's not that clear whether they're actively hunting the insects, or just kind of accidentally eating them when they visit the flowers.

ARA: So, how long have people, in general, been studying nectar bats?

NM: It's fairly new. So, the taxonomy behind nectar bats would be based on a bat maybe in the mid-1800s, in other words just taking specimens to museums, describing the different types of species of nectar bats... but, you couldn't really study nectar bats, or bats in general, in much detail until scientists started using mist nets. And these are really fine net, basically like fishing net, that you set out at night and catch the bats in. Before they could do that it was a lot more difficult to study them.

ARA: So, do you use a mist net with your research? What would be involved in a typical night of you collecting data?

NM: A typical night would be, I would set up the nets first, when it's still light outside. And then you open them [after dark]. You choose places in the forest like, maybe crossing paths, places where you expect that they'll be flying around, and in front of flowers , of course, if you think that they visit certain flowers. So I would set up the nets and then, the rest of the night, I would wait somewhere nearby the nets and check them every half an hour and remove any bats that are captured. And, for nectar bats, I would take the pollen off of their fur. So, any pollen that's on their fur, that's a record of what they've been visiting recently. So, that's the main data that I collect. But then I also do a lot of experiments with them, where I'll hold them for a few days before releasing them. I'll hold them in a screen tent and try different experiments as far as which flowers they prefer, how the length of the flower affects how well they pollinate, things like that...

ARA: So, when this particular bat is visiting this flower that you were talking about, where does it collect the pollen on its body?

NM: On the top of the head. So, this is one way that plants share bats as pollinators. Bats basically want to visit anything in a forest. So, plants often have the problem of how do they guarantee that they're getting pollen from the same species? How do they avoid having their pollen mixed up with pollen from all the other plants in the forest? So, one thing that they can do is they can put the pollen on really precise regions of the bodies of bats. And, so this particular plant, *Centropogon nigricans*, uses the top of bats' foreheads.

ARA: Where does the pollen end up for other flowers?

NM: Different species use just about every part of bats. There's some that put them under bats' wings, there's some that just use bats' bellies, there's a species of bromeliad that uses pretty far down the back of the bat.

ARA: Oh, ok. I didn't realize there was so much diversity in where it would go. I was just thinking they stick their face in, and that's where they get it.

NM: There's flowers that'll have the cup that they put their head in is pretty small, but they'll have those long anthers that go all the way back to the back, or under the bat. And then actually it turns out that the position of where they're putting their pollen on the bat's body is really important to whether they coevolve with the bat or not.

ARA: What do you think are some interesting results of your recent research?

NM: Well, so one thing I was trying to figure out now is why this bat would evolve such a long tongue. So this new species of bat is pretty remarkable in that it's tongue reaches so long and that it stores it in the ribcage when it's not extending it, so that's not typical for many other mammals. Anteaters actually do that, but no other bats do that. So, why would it have evolved such a long tongue? I did some experiments where I found that longer flowers are pollinated better by the bat. But I couldn't quite figure out

why that is; what's the benefit of having a longer flower? A good start is that the flower can specialize on just one of the bats in the forest. So it can avoid, maybe, the other bats in the forest that don't do as good of a job at pollinating it. But, in this particular case, the length of the tube is a lot longer than any other bat could reach. Six cm would be long enough to prevent any other bat from reaching it [the nectar], but the tube goes out to 9 cm.

ARA: Oh, wow. So, how long is this bat's tongue in relation to other nectar-feeding bats?

NM: Let's see, the next longest is probably about 50% as long. [For] other bats in the same genus, it's twice as long.

ARA: Now, is that for bats all over the world, or just in the neotropics?

NM: This group of bats is just in the neotropics. Nectar bats that can hover in place, they're from a certain subfamily that only occurs in the neotropics.

ARA: Oh, ok. Are there bats with really long tongues in the Old World tropics?

NM: They're fairly long, but they're not as specialized as New World tropics bats. They're fruit bats, and there aren't many species that are super-specialized to just feeding on flowers. Most of them also eat fruits.

ARA: So, am I getting this right- this bat has the longest tongue of any bat discovered so far?

NM: Yep. It has the longest tongue of any bat. It has, relative to body length, it's actually the longest of any mammal.

ARA: So, it stores its tongue in its ribcage...

NM: Yep.

ARA: And, where do other longue-tongued bats put their tongues?

NM: It's just like a regular mammal, that it's in the mouth. If you look at the length of the jaws for all other nectar bats, it predicts how long they can extend their tongue really well. In other words, the ones with longer tongues have longer jaws.

ARA: Right, ok. Cool! So, what are some particular challenges that are unique to this kind of research?

NM: Well, it's trickier to study bats because they're nocturnal, so it's tough to get a complete picture of pollination. During the day you can watch a bee pollinating and see where it goes next. You can't really track bats very well, so that can get tricky. I tried to use what they call "camera traps," on bat flowers, but that didn't work at all, because their visits are too quick. Their visits are about, like, half a second long.

ARA: Oh! Wow!

NM: Yeah. So, even the fastest camera trap I could find wasn't fast enough to get them visiting flowers.

ARA: Now, how much nectar are they taking up in that short [of] a time period?

NM: They manage to extend their tongue to lap up about three times in that time period.

ARA: How many flowers do these bats typically visit in one night?

NM: I've seen studies that looked at how much energy they need per night, and how much energy a single flower can give them, and those predict that they need to visit about 3,000 or 4,000 flowers per night.

ARA: Wow. So are they mostly finding these flowers by the smell?

NM: That's not that well-known yet. And I actually worked with a student who was studying that last year in Ecuador. It looks like both echolocation and smell are important. I'm not sure which is more important in which phase of searching. In other words, maybe as they're flying through the forest first they rely on smell, then once they

get closer then they have to switch and rely more on echolocation. But definitely those are the two signals that are most important for them.

ARA: Right.

NM: The flowers are often really well-exposed beyond the leaves of the plant, so the echolocation can pick them up well. And there's pretty neat petals that you see a lot of bat-adapted flowers have, that are like radar dishes, basically, that reflect the echolocation really well, and real specifically back at the bats.

ARA: Cool. Does this bat feed on more than just this one flower?

NM: Yeah. Ok, so that's where it starts to get interesting is that the flower is really specialized to the bat, but the bat feeds on, so far I think I've recorded it feeding from maybe 15 or 20 different flowers throughout its range. So, depending on the habitat you find it in, it's feeding on different things. And even in habitats where the long-tubed flower occurs, it's also feeding on other plants at the same time. Here's where I found something interesting- I actually haven't been able to publish this yet, I just figured this out; I found another species of flower that also evolved a really long tube. The ones that evolve the long tube are the species that use the top of bats' heads.

ARA: Oh...

NM: It took me a while to piece this together, but there's other species that use the bellies, species that use the wings- those don't evolve really long tubes. But what I figured out- I did some experiments in flight cages- for whatever reason, when the tube is longer, and they have to stretch further down into the flower, they lift their heads up more.

ARA: Oh, ok...

NM: So, only flowers that are using the tops of bats' heads get any benefit from having longer and longer tubes from kind of forcing them to really stretch and lift their head up.

ARA: Right, interesting. So, are all of the flowers that this bat visits... do they all have relatively long **corollas**?

NM: Nope, I've only found two species that have evolved really long tubes. All of the other ones have about... maybe a maximum of 4 cm- long tubes, so other nectar bats can also feed from them.

ARA: So, now, in the southwestern U.S., I'm thinking, cactus flowers, are pollinated by bats, and they're kind of like- for people who aren't familiar with what they look like- they're sort of like an open dish with a bush of anthers, and the bat just sticks its face in it. Are there flowers that look like that that are bat-pollinated in the tropics, or are they mostly tubular...?

NM: No, cactus flowers are pretty different from tropical flowers- lots of them have tubes with the nectar at the base and then the anthers put pollen on the tops of bats' heads or the back of their backs. They tend to be bilaterally symmetrical, rather than radially symmetrical. So, you could take a plane through a radially symmetrical flower through it in just about any direction and cut it in half. Bilaterally symmetrical is like humans; there's just one plane that you have mirror images. So, yeah, so tropical bat-pollinated ones, just about every one that I know of is bilaterally symmetrical.

ARA: Ok. That's interesting. So, it's more like tropical bat-pollinated flowers are more like what someone would typically think of as a hummingbird-pollinated flower.

NM: Yeah, they often look really similar. They often evolved from hummingbird-pollinated flowers.

ARA: Oh, ok!

NM: That might explain why there's a connection there.

ARA: So, there's evidence that the flowers switched from hummingbird to bat pollination?

NM: Yeah. I spent some time looking at all different examples in the tropics that I could find of bat pollination and, in just about every case, when a plant evolves bat pollination its ancestors were humming-bird pollinated. I found there's one instance of a switch from bee pollination to bat pollination.

ARA: Wow, neat!

NM: It makes sense, because morphologically they look pretty similar, they're producing a similar amount of nectar, and the body sizes are similar.

ARA: So, a lot of people, I think, when they hear the word, "bat," they think of, 'a critter that lives in a cave that's going to suck my blood.' So, hopefully, listening to this podcast, they'll understand that there are actually a lot of nectar-feeding bats. But, where do these little bats sleep during the day?

NM: Yeah, they do sleep in caves. It's not as well-known in habitats I work in, in tropical forests, when they don't have caves, where are they sleeping. But they've found them in just dead bunches of leaves in trees, or in trunks of trees. So, no, they don't have to sleep in caves, but they will use caves when they're available.

ARA: Ok. What has been your favorite part about working with this bat?

NM: I think the discovery. I think learning new things; bat pollination isn't that well-known, so often I'll find flowers that are bat-pollinated that people haven't realized that, that it's not described in scientific literature.

ARA: Yeah. Can you think of anything that might relate it to people?

NM: Let's see... so, there's some agricultural crops that are bat-adapted. **Kapok trees** are bat-pollinated. There's a lot of fruits and cacti that people use to make jams and jellies.

ARA: What's one thing that people can do to help bat pollinators if they live in an area that has bats?

NM: Helping in conservation efforts; bats need their forests. For example, the forests that I'm working in are cloud forests.

ARA: Did you say these bats are in a cloud forest?

NM: Yep!

ARA: What, exactly, is a cloud forest?

NM: Cloud forests are high-elevation tropical forests. They're really diverse, not quite as biodiverse as lowland rainforests, like the Amazonian rainforest. But they're different in that they're almost constantly covered in clouds, often really low clouds. So, the forests themselves are misty, [and] they tend to have lots and lots of epiphytes, of plants living on other plants.

ARA: Uh-huh. So, are these habitats threatened by deforestation?

NM: Yeah, they tend to make for good farmland. So, a lot of the habitats are getting destroyed just by people needing farmland or grazing land for their cows.

ARA: Right. Well, thank you so much for your time today!

NM: Sure. Thanks for having me on your podcast.

ARA: Once again, thanks for joining me. I'm Athena, the author of pollinators.info and you've been listening to podcast episode 3, an interview with Dr. Nathan Muchhala. If you'd like to join the Pollinator Conservation Movement, just stop by pollinators.info, click on the 'Subscribe Here!' page, give me your name and email address, and you'll get a free weekly email newsletter, and FREE STUFF! And, don't forget to stay tuned for next month's podcast. Take care, now.

Podcast Episode 4: Interview with Dr. Nathan Holland

Quick Glossary of science terms that aren't explained in this podcast:

- Population dynamics: these include reproductive rate, death rate, immigration and emigration rate.
- Positive feedback: this happens when a result causes an increase in more of the same; in this case, an example would be that one female moth laying more eggs on cacti increased the number of female moths that laid more eggs than their mothers, and so on.
- Mutualistic species: these are species that benefit each other.
- Obligate mutualism: these are species that MUST interact with each other to survive.
- 10mm= 0.4 inches
- 4- 5 meters= 13- 15 feet

Athena (ARA): Hi there! I'm Athena, the author of pollinators.info, and you're listening to podcast episode 4. This is an interview with Dr. Nathan Holland, who studies senita cactus and senita moth pollinator interactions.

Well, first of all, thank you so much for your time today and for joining me to do a podcast!

Dr. Holland (NH): No worries.

ARA: I'm excited that I could find someone to talk about moths! A lot of people don't realize that moths are important pollinators too.

NH: That is very true. They're often under-appreciated. They're out at night, and people don't often go out at night as often.

ARA: Ok, so how would you describe your job, or what is your position, so people will know what it is that you do?

NH: Ok, so I am a research professor at a university, and my job entails teaching, as well as research that future generations will learn from.

ARA: And where do you teach?

NH: I am, right now, with the University of Houston.

ARA: Ok. How would you briefly kind of sum-up your research with the senita moth and the cactus?

NH: Well, I initially got interested in this system as a model system in which to investigate theory about positive interactions between species that have positive effects on both of the species. And, so, this is a fairly specialized system, and a one-to-one relationship between the moth species and the cactus species, and that made it fairly tractable for me to develop theory and test it in nature to understand two major questions:

1. What determines the **population dynamics** of the interacting species?
2. And, why doesn't this **positive feedback** lead to **mutualistic species**, such as moths and cacti, just growing indefinitely?

ARA: Now, can you explain what you mean by a one-to-one relationship with the moth and the cactus?

NH: By one-to-one relationship, I mean that the cactus has a pollinator, and that pollinator is the one and only pollinator. And, in turn, the moth has one plant that it pollinates, and it interacts with that one, and only one, plant.

ARA: Oh, ok. So, this would be an **obligate mutualism** between the two?

NH: Right, so it's very much so an obligate interaction which, as we're learning, that such systems are less common than we previously thought. So, in nature, most plants are pollinated by many different species, and many pollinators interact with many different plants. And, it's less common to have just one pollinator that interacts with one

plant, and one plant that depends on just one pollinator. That leads to some ecological issues that can be problematic if one or the other disappeared.

ARA: Right, so what, specifically, are you looking at with this system?

NH: One of the issues I'm trying to address and understand, which we've studied in ecology for many, many decades with other types of species interactions, is: how does the density of the moth, as a mutualist, influence the reproduction and consequently the density of the cactus? So, how is it that abundance influences, shapes, and molds the interactions between the moth and the cactus? Because you can imagine that we generally think that more is better, you know, "More cake for me after dinner!" So, often times we think about that in terms of mutualism, but it may actually be the case where more is not better.

ARA: Ok. So, in this case, what exactly would that mean? More moths are not necessarily better for the plant?

NH: Right, so as it turns out, the senita moth is kind of like yucca moths; it's doing the plant a really great service by pollinating the plant. But the moth also, while pollinating, the moth lays its eggs in the flowers. So, young [moths] depend upon the developing fruit of the cactus that their mother's pollinated, which makes it a bit of a tug-and-pull relationship for the cactus. The cactus needs the adult pollinators, but it also pays a small price in giving away some of its developing fruit. So, more moths is good because you get more pollination, but you also get a whole lot more eggs. So maybe it's better, in terms of the abundance of the moth, to have an intermediate number of moths, so that not too many eggs are laid, but a lot of flowers are still pollinated.

ARA: Right, so it's a tricky balance. And, is that something you're looking at; what is the optimum number of moth eggs?

NH: Exactly. So, we're looking at, in this cactus, does the cactus have any sort of strategy it can employ to keep moths from becoming overly abundant, and what is the

consequences of that strategy for moth abundance. And, it turns out that the cactus likely does have a strategy to regulate moth population at levels that are best for cactus reproduction.

ARA: Ok, interesting! So, just so that people have an idea of what kind of animals and plants we're talking about, can you briefly describe what this moth looks like?

NH: It's a fairly drab moth; it would largely go unnoticed if you weren't really paying attention to the cactus. The moth is, maybe, **10mm** [long], is pale in color, and has one little grey stripe, one thin little grey stripe, going down each of its visible wings. It's really a nameless moth in the Sonoran Desert.

ARA: What's the scientific name?

NH: The scientific name is *Upiga virescens*.

ARA: Ok. It's got no common name?

NH: Well, its common name is that of the cactus; we call it the senita moth.

ARA: Oh, ok. Like a yucca moth. And, a lot of people have never been to the desert southwest. It's one of my favorite places, because I think cacti are so neat! So, could you tell us a little bit about the senita cactus and what's its range, and what does it look like, and when does it bloom, and that kind of stuff?

NH: Right, so the senita cactus is a columnar cactus and, so it's in a group of cacti that have many, many stems that are like columns, hence the name 'columnar cactus.' And it's one of four species that are occurring in my main study site in Sonora of Mexico. Columnar cacti, in general, are, if we've watched some old John Wayne movies from way back when, we'll remember seeing those images [of cacti] with one arm up and one arm down. And, the senita is a little different from that cactus, which is the saguaro cactus, in that the senita cactus will have many stems that radiate from the base of the plant. These stems can range in number from a young plant that might have 15 or 20, to

an older plant that might have 100 or more. And these stems can get up to **4 and 5 meters** in height. So, they get very tall.

ARA: So, that's like 15 feet. Wow! Yeah! so what's the range of the senita?

NH: So, the senita cactus, unlike many of the cacti in the Sonoran Desert, the senita cactus is actually endemic to the Sonoran Desert. It's most northern limit is just North of the US-Mexico border, in Organ Pipe Cactus National Monument. There's a place in that park called Senita Basin, and it's named after the cactus. Their southern distribution goes all the way down to the bottom of the state of Sonora [in Mexico], along the Sea of Cortez, the Gulf of California, and barely into the state of Mexico just below the state of Sonora.

ARA: Ok, neat. So, what do the flowers look like, and when do they bloom, and where are they on the cactus?

NH: The flowers are typically located at the tops of the stems, rather than the bottoms of the stems. So, you might have the top 2 or 3 feet of the stem that's flowering. It'll produce dozens to almost 50 flowers sometimes per stem.

ARA: Oh, wow!

NH: The flowers usually are produced anywhere from early April through late July. I've heard of cacti that can produce about 3,000-5,000 individual flowers. The flowers are fairly small, maybe an inch and a half across. The flowers are pale white to sometimes very pink [in] color.

ARA: So, what exactly happens when a female moth pollinates, and then where does she lay the egg; what does she do in the flower?

NH: Well, it's unique because most moths, and most pollinators in general, visit flowers for the incentive of the food resource the flower is providing to the pollinators. So, that's usually nectar and, in some cases, pollen. Well, the incentive for the senita moth to visit the flower is more as a place to lay her eggs than it is for nectar resources.

So, flowers don't tend to contain a lot of nectar. So, the first thing a moth will do is pollinate the flower, and it engages in a, what we refer to as specialized 'active pollination' behavior, whereby the moth liberally rubs pollen from her abdomen onto the [plant's] female reproductive part, the stigma. So the females [moths] will then lay an egg, usually on the petals of the flower, before she departs that flower to go on to another flower of another plant. The flower itself opens at night and closes, usually, by the morning, and within 3 or 4 days, the egg has hatched and the larva is crawling into the fruit of the cactus where it's going to eat some of the developing seeds that are the response of the mother's pollination.

ARA: Ok, now, with yucca moths, I know that the yucca flower doesn't ever really open much, so nothing else ever really goes into a yucca flower. Does the senita flower function the same way, or does it ever open up so that something else visits it?

NH: Oh, no, it's quite different. In fact, senita flowers do open all the way up. They're exposed to many different insects and [other] animals. We see insects that eat flowers on the plants sometimes, we see insects that are in the flowers looking for nectar, but they don't find it because just not much nectar's there.

ARA: So, do the flowers have lots of pollen like most cactus flowers?

NH: They're much reduced in size and shape, compared to some of the big bat-pollinated flowers. Those bat-pollinated flowers just have copious, copious amounts of nectar and pollen. These flowers are smaller and have much less pollen and much less nectar.

ARA: Right, so even though other things visit it, the senita moth is the only one that pollinates? Or is it the only one that pollinates effectively? Or, how does that work?

NH: It's largely the only pollinator. There are a few co-pollinators; some small, beautiful bees, called Halictid bees that in the morning hours, just around sunrise, can

visit the flowers and do a little bit of pollinating. Our experiments show that these bees are largely unimportant [to pollination] for two reasons:

1. One, the bees visit the flowers after the moths, and so the moths have already done the job,
2. And two, often because it's hot in the Sonoran Desert, often the flowers close before sunrise; the bees are unable then to access the flowers.

ARA: Right. What are some particular challenges involved with this research?

NH: Well, Athena, there are always professional and personal challenges. One of my personal challenges is not eating too many fish tacos in this beautiful fishing village that I work in. That is a true encumbrance. But, realistically, some of the challenges posing scientists as a whole now are the same challenges that are posed to me as an individual investigator, and that's having enough financial funding to get out and do the research to help provide the intellectual material for the textbooks for our children. So, you know, it financially can be expensive, and it's important for our government to continue to support such funding. In a more practical sense, my work occurs at night, at late hours, and as I get older being up at 2 in the morning and working with pollinators isn't as easy on my body as it was when I was 25 so, sometimes the nocturnal work can be challenging. And then, being in the desert for me isn't a hardship or a challenge, though some people find the desert environment a challenge. I actually find the Houston humidity more of a challenge than I do the dry desert heat.

ARA: (Laughs) Ok, so what do you like most about it, besides the fish tacos?

NH: (Laughs) Well, for me it's really into nature, and being able to look at some really important, fundamental questions that will help us to understand how nature operates, and to be able to collect data, learn about a system in nature that might apply to other systems and to mutualism and pollinators in general. So, it's a lot of the

intellectual work and then just being in the desert at night and, while it can be tiring, it is also just an incredibly beautiful place to be anywhere in the world at night- absolutely gorgeous. There's not a lot of light, there's lots of starts, and the silhouettes of cacti against the moon, and when you take a moment to enjoy those scenes, between your looking at the flowers and the moths and collecting the data, it's really quite tranquil.

ARA: Right. So, I try to, in all the podcasts, relate the research to the general public somehow, so that people will understand, "Well, why should I care? Why should the government spend money on this moth in Mexico? What does that have to do with me?" What kinds of things would you tell someone that you met eating fish tacos that this relates to them and their life?

NH: Right, so that's a really good question, and it's a really important question, and I think the answer is probably best conveyed via analogy. We talked earlier about how this is a one-to-one relationship and an obligate relationship. And, in this particular case, if you went out at night and didn't know the moth existed, you probably wouldn't recognize that it was there and around doing much of anything. In many cases, this is true of many nocturnal, and in particular, moth pollinators, because the moths aren't the charismatic species that lots of people want to reach out and say, "Wow!" And, we often don't see them and notice them because they are occurring at night and they are typically less beautiful than the diurnal butterflies. But this particular moth, as an example, can be analogous to the small pieces in a mechanical watch. So, you can imagine yourself opening up the back of a watch to change its battery, and you can see some important pieces. You know that if you remove one of those important pieces, that the watch is going to stop working and we just aren't going to be able to know what time it is. But there are also other little pieces down in that watch that you can't really see, and those are analogous to this particular moth, and many moths in general that are important pollinators. Whereby, if you remove the moth, or that little small piece in the

watch that you don't see, then the system, the watch or the ecological system as a whole, can start to break apart, and so would some of the things that society depends upon, as a whole, can diminish.

ARA: Nice!

NH: So, many of these cacti, for example, and the senita cactus is one such example, produce fruit that are very good, and enjoyable, and some indigenous as well as local people use and consume and make jelly out of [it]. So, if we lost the pollinators, the moth pollinators, then we would no longer have some of these wonderful jams and preserves that are bought in Mexico or in Arizona that people will send as holiday gifts to their relatives.

ARA: Yeah. So, like the saguaros, the senita was probably [an] important food resource, and maybe a textile resource for the dead spines, to native cultures, before European settlers got that way.

NH: Exactly, exactly.

ARA: Cool, ok. What would you recommend to people who want to help pollinators in general, or moth pollinators specifically? Do you have any recommendations for things people could do?

NH: Yeah. There's always non-profit organizations that will accept donations, and that also fund research. You know, like in the Sonoran Desert there's the Arizona-Sonora Desert Museum. I guess for pollinators in general, for someone who might be interested, I would actually recommend a book that came out, I want to say just a few years ago, but now that I think about it, it's probably been over a decade now. But it's a book by Dr. Steve Buchmann and Dr. Gary Nabhan called The Forgotten Pollinators.

ARA: Yeah, it's actually been more than a decade, it's hard to believe, isn't it? (Laughs)

NH: So, I don't know if we're aging ourselves... [but] so, that's a really great resource for just enjoyable reading and education on pollinators as a whole that's written to the scientist and to the non-scientist alike, and it's just a wonderful read. So, I highly recommend that, and that has some resources within it to direct people to how they can help with pollinators.

ARA: Something that I like to always encourage people to do is plant a native garden, with native plants! If you're lucky enough to live in the southwest, you know, if you look for all kinds of fun cacti and other succulents, and just native wildflowers, you're going to be providing food to, maybe not the senita moth if you don't live in its range, but pollinators that'll visit those plants at night and pollinators that'll visit those plants during the day... So, something that I try to get people to do is think about natives when you're planting.

NH: Absolutely, absolutely. And I think that what you're suggesting, Athena, is really appropriate for wherever you live, whether it be in very cold parts of Alaska, or whether it be in the humid summer months of Athens, Georgia or Houston, Texas, we can engage in something that Dr. Mike Rosenswag at the University of Arizona refers to as reconciliation ecology. And, that is sort of doing backyard ecology- to utilize our own yards to put in native plants that help, in urban areas, the local natural resources, such as moth pollinators, to be able to continue to persist. That's really an important point you've made.

ARA: Yeah. Ok, well thank you so much for your time today!

NH: Thanks very much, Athena! Good luck with your projects and your work- I'm really pleased to know that somebody's out there doing what you're doing.

ARA: Once again, you've been listening to pollinators.info podcast episode 4. I'm Athena, the author of pollinators.info, and this was an interview with Dr. Nat Holland, who studies senita moths and their obligate mutualism with the senita cactus in Mexico.

Stop by pollinators.info to learn all kinds of neat stuff about pollinators, and the plants that they visit, and how you can help pollinators. And join the Pollinator Conservation Movement by signing up for the free weekly pollinators.info email newsletter! And, did I mention you'll get free stuff? There's free stuff! There's free stuff now, AND there'll be more free stuff in the future! (Laughs) So, once again, thanks for joining me, and stay tuned for next month's podcast. Take care!

Podcast Episode 5: Interview with Dr. Ted Fleming

Quick Glossary of science terms that aren't explained in this podcast:

- Columnar cacti: these cacti grow in what look like columns. Saguaro has one main stem with smaller stems that grow from its sides. Cardóns have more than one stem growing up from a base.
- Reproductive success: this describes an individual's ability to reproduce; in this case, become pollinated and set seed.
- Geographic variation: this is something that changes with some aspect of the landscape. In this case, the saguaro pollinators change with latitude.
- Netting: scientists use a fine mesh net, called a mist net, to capture birds and bats, without harming them, for study.
- Bagging flowers: by putting a mesh bag over a flower, a scientist can prevent animals from visiting it. If flowers that were allowed to be visited have higher fruit set than those that weren't, this suggests that the animal visitors were important pollinators.

Athena (ARA): Hi there! I'm Athena, the author of pollinators.info, and you're listening to podcast episode 5. This is an interview with Dr. Ted Fleming and he's going to be talking with us about lesser long-nosed bats and pollination of saguaro cacti, and also his research monitoring hummingbird feeders in the southwestern US.

So, how would you describe your position, or what is it that you do?

Ted Fleming (TF): Well, for almost 40 years I was a university biology professor, and I retired in 2008. I guess I'm retired in quotes, because my wife would deny that I'm really retired. I'm very busy with an academic schedule, even though I'm not teaching very much, but I'm writing, giving talks, and attending conferences.

ARA: So, how would you describe your work with the bat and the cacti in their natural environment, and then with the feeders?

TF: Well, in 1989 I was invited to begin looking at the role of the lesser long-nosed bat as a pollinator of giant columnar cacti in Sonora, Mexico. In 1988 this bat was declared federally endangered, both in the United States and in Mexico, so there was quite a bit of concern as to what would happen if this bat were to disappear.

How would this affect the reproductive success of giant cacti, such as saguaros, organ pipes, and cardóns? So, Merlin Tuttle, the founder of Bat Conservation [International], and I got a grant from National Geographic to do experimental studies demonstrating the importance of these bats as pollinators [for] these giant cacti.

ARA: Ok, so how long did you do that study?

TF: Well, we began in 1989 and it really ended in 2000. By that time we had lots of experimental evidence, from our study site in Sonora, Mexico, as well as one study site in western Arizona- the Organ Pipe Cactus National Monument, that bats are indeed important, but not the exclusive pollinators of columnar cacti. It turns out that, in the northern part of the range of these cacti, which is the Sonoran Desert, bats, as well as birds and bees, are important pollinators. In contrast, if you go farther South, in arid parts of Mexico, and also in the arid parts of tropical Venezuela, bats become the exclusive pollinators of the columnar cacti there.

ARA: Interesting!

TF: In the northern part of the range, bats share pollinator duties with diurnal species, such as birds and bees.

ARA: So, which birds are involved in the cactus pollination?

TF: Well, in the Sonoran Desert, the saguaro cactus is most heavily pollinated by white-winged doves, and organ pipe cactus are most heavily pollinated by hummingbirds.

ARA: Oh, interesting!

TF: Only the cardón, of the three that we've studied intensively, relies almost exclusively on bats for pollination.

ARA: Ok, neat! Did you guys do any research into why there might be a difference in pollinators from the northern to the southern range of the cacti?

TF: Well, the key difference in the geographic variation is the resident or migrant status of the bats in a particular area. In the Sonoran Desert, the nectar-feeding bats are only seasonal and their numbers fluctuate from year to year.

Farther South, in arid parts of tropical Mexico, as well as arid tropical Venezuela, the bats are residents year-round, so they are a more reliable visitor in the tropical latitudes than they are at northern lats. And, as a result, species such as saguaro really shifted in the time of flower opening and closing to take into account the greater reliability of diurnal birds as pollinators.

ARA: So, what's a little bit about the monitoring that you're doing with these bats and hummingbird feeders?

TF: Well, it turns out that nectar-feeding bats are residents in southern Arizona from spring to the fall, but they feed on different flower resources during this period. Early in spring and in the summer, they're feeding on flowers and fruits produced by columnar cacti. In the fall of the year, they switch their feeding to century plants- agaves- which occur out of the desert zone in a little higher elevation. So, the bats are pretty much supplied with flowers from the spring through the fall.

But we know that lesser long-nosed bats and Mexican long-tongued bats have been frequent visitors to hummingbird feeders [in eastern Arizona] for decades. But, beginning in 2006, people throughout Tucson [Arizona] began to find that their hummingbird feeders were being drained at night, and when they watched their feeders at night they saw nectar-feeding bats visiting them.

This is a new phenomenon. So, it turns out that lesser long-nosed bats spread throughout the greater Tucson area as visitors to hummingbird feeders only in the past few years. We are now monitoring this phenomenon and we have a network of over 100 citizen scientists who report to us via a website. And, people are reporting when the bats first show up in their yards in the late summer [and] early fall, when they leave their yards in the fall, [and] when the peak numbers of bats occur. And many of these people have taken digital photos of the bats so that we can identify which of the two species are actually visiting their hummingbird feeders.

ARA: Ok, neat! Can you tell us a little bit about the bat's life history? So, we're mostly talking about the lesser long-nosed bat... so, what does it look like, and just a little bit about its reproduction and natural history?

TF: Ok, the lesser long-nosed bat is a very handsome bat; I've worked with bats in many places in the world, and it turns out that the lesser long-nosed bat is my favorite bat. Adults are fawn-colored and they have big, bright eyes, and a somewhat elongated snout. They have a little flat triangular flap of skin above their nose, which identifies them as [part] of the American leaf-nosed bat family.

These bats are specialized nectar feeders, but they don't eat nectar exclusively. They also eat fruit; they will eat fruit of the columnar cacti, whose flowers they pollinated. They also eat insects occasionally. These bats are migratory; they spend their winter in south-central Mexico. In the fall of the year, females and males congregate in particular mating caves. Females become pregnant a month or so later and they begin to migrate North, feeding on the flowers of columnar cacti.

By early April, they are in northern Mexico and in southern Arizona and females form maternity roosts. These roosts can contain tens of thousands, and one roost contains over 100,000, pregnant females. Females give birth to a single baby, beginning in mid-May, then the mother nurses the baby for about 6 weeks, then the young is

nutritionally independent [from] mom, but it still forages with its mom when its mom is out visiting flowers or fruit. So the mother-young pair, we think, we don't have banded bats so we can't know for sure, but the mother-young pair probably stay together for most of the season when they're in the North.

Then all of the bats migrate back down South, beginning in early to mid- October. The bats are here in our yards in Tucson from about mid-August to mid-October. Very few adult males migrate North. Females actually do have to migrate in the case of lesser long-nosed bats, because they're migrating from southern Mexico to the Sonoran Desert, where you have an abundance of flower resources [and] fruit resources- much higher than would be the case in south-central Mexico.

ARA: So, can you tell us a little about the natural history of the saguaro?

TF: Well, the saguaro and the cardón are two very iconic species in the Sonoran Desert. The saguaro, of course, is the dominant columnar cactus around Tucson and southern Arizona. The cardón doesn't get quite as far North; it's restricted pretty much to Sonora and Baja, California.

They're both very large, they get to be 20 meters tall (about 60 ft.), sometimes they weigh tons; they're huge plants. They produce lots of flowers. In the case of cardón, the plants are highly dependent on bats. Saguaros are "hedging their bets," and make their flowers more available to diurnal visitors, such as the white-winged dove. Flowers open first shortly after sunset in the case of the cardón, a little bit later in the case of the saguaro.

Flowers of cardón close the next morning [permanently], an hour or so after sunrise, whereas the flowers of saguaro stay open until that afternoon. So, the saguaro flowers are exposed to diurnal visitors for a much longer period of time. And, it's no surprise to find that saguaros are much more cold- tolerant and are the most northern in distribution [of the columnar cacti], because they can have pollination by birds

throughout their range, whereas bats are not pollinators North of Tucson, for example, in Arizona. Saguaros go much farther North in Arizona than just Tucson and white-winged doves are the ones doing the pollination up there.

ARA: What are some major results from the studies that you did?

TF: Well, we found some very fascinating things. For example, it takes about 8 or 9 flower visits to recoup the cost of flying up to 25 miles- that's 8 or 9 visits out of a total of 100 or 120 flower visits a night. So, it's a really low cost to commute long distances to good feeding areas.

ARA: So what are some results that you're getting from people sending you information about the feeder usage?

TF: Ok, what we're learning is that in most years, bats arrive in people's yards on a very predictable date. In my yard, for example, they arrived on the 3rd or 4th of September in 2009 and 2010. Things changed this year; the bats in my yard, and in many other yards, began arriving at least 2 weeks earlier. We don't know why this is, but we think it's linked to the availability of natural food resources, such as the agave, or century plant. This was not a particularly good flowering year for those plants and so the bats probably moved into the urban areas earlier than they normally would because of the absence of food resources in the wild.

We also know that the majority of people are tracking 10, 15, 20, 30 bats coming to their yard to their feeders. In my yard, I typically get 2-5 bats visiting my feeder per night. This year we actually netted bats in my yard one night and we caught 12 different individuals. More bats were feeding in people's yards this year, which suggests, again, that their natural food supplies were low this year.

Most people, once they begin monitoring these bats, get hooked on it. They love the bats! They're very tolerant of being observed at very close range, they don't mind

being photographed, so lots of people get great pleasure out of discovering that they have nectar-feeding bats coming into their yards on a seasonal basis.

ARA: Yeah. That would be so neat! So, has there been some sort of major change in habitat destruction or flowering that you all think has driven the bats to use feeders, or is it just that they're just such a good source [of food] that they're using them because they're there?

TF: Well, I think it's a very opportunistic thing. Once the bats discovered that feeders were everywhere, I think the word spread. We have no evidence of this, but just the behavior suggests that there had to have been communication. The year 2006 was definitely a year of low agave flower availability. They were forced to feed into town, and once they got hooked on this nectar, they kept going back year after year.

ARA: Interesting... Has anyone looked at the actual nutritive content of the sugar at the feeders? Are the bats getting the same kind of nutrition that they would at an agave?

TF: We know the sugar content, because we can control the sugar content of our feeder nectar. It's pretty much the same as the bats would encounter in either cactus flowers or agave flowers; about 25% sugar. That's fine. But what is missing from feeders, of course, is pollen.

The bats really need pollen to build proteins. Pollen grains have amino acids and the bats can digest the grains, get the goodies out of the grains, and with the amino acids they can build proteins. They don't need to eat insects because they can get a balanced nutrition from the nectar and the pollen from natural cactus or agave sources.

So the feeders only supply the energy that the bats need, but we know from just watching the bats, and taking pictures of the bats, that they come in with pollen on their faces in some cases. And they know they can discover pollen sources, most of these are exotic plants, plants that aren't really native to the Sonoran Desert, such as the night-

blooming cereus cactus, which is a plant from farther South. But the bats discover these little pockets of good pollen sources, so they actually do get a balanced diet as a result of feeding on nectar in the feeder and then finding supplementary flower sources.

ARA: Now, what has been your favorite part about the work with this bat?

TF: Oh, it's just watching the bats interact with the flowers. I've sat out in the desert, staring into night vision scopes. Actually, sometimes when I'm doing experiments up on a ladder, putting bags over flowers, I can see these bats in action right up-close [and] it's always a very fun thing. And again, in my own backyard, I can stand out near a hummingbird feeder and watch these bats come in. And they forage in groups, so I can see 2 to 4 or 5 bats zipping around my yard and visiting my two hummingbird feeders on a regular basis. So, it's a very pleasant thing to do.

ARA: What are some broader impacts of this, just so that the general public, or someone who doesn't know much about bats or desert ecology, if they're listening to this, how can we make it so that they understand that this is important to them?

TF: Well, the general importance is much greater than just our studies of lesser long-nosed bats and cactus. There are, in the neotropics, 38 species of nectar-feeding bats. They're visiting hundreds of species of plants, and some of these plants, like the columnar cacti and kapok trees, are some of the dominant plants in their particular habitat. Certainly, if the bats were to disappear from southern Mexico, columnar cacti down there would be in big trouble; we wouldn't have columnar cacti.

Tequila is an extremely valuable resource in Mexico, as I'm sure you know, and tequila plants, the agave, ancestrally evolved to be bat pollinated. Now, tequila plants don't need bats for pollination because they are harvested before they put up their flowering stalks. But nevertheless, if we didn't have nectar-feeding bats, we wouldn't have agaves that produce a very important crop.

And around the world there are just a number of very important resources, bananas for example, that are ancestrally bat pollinated. Bats have played a very important role in the evolution of flowering biology in many species, many families, of tropical and subtropical plants. And some of these species have very significant economic importance.

ARA: Ok, what would you recommend to people that want to help bats in particular, or pollinators as a group?

TF: Well, have a very positive attitude towards bats, rather than a negative attitude. I think, certainly in Latin America, also probably in the United States and Canada, the general public has a negative view of bats because they get bad press whenever there's a case of rabies. So, everybody fears bats because they transmit rabies.

Well, dogs, cats, skunks, raccoons, you know, lots of mammals transmit rabies. Bats are no more likely to be infected with rabies than lots of other mammals. And they certainly aren't likely to transmit rabies to the general public. It ain't gonna happen. It happens rarely- Merlin Tuttle often said you're more likely to die of food poisoning from a church picnic than from rabies transmitted by a bat. Or you're more likely to be struck by lightning. Of course, more people die [every year] from bee stings and anaphylactic reactions than die from rabies from bats.

ARA: Ok, well Dr. Fleming, thank you so much for your time!

TF: Yeah!

ARA: Once again, you've been listening to pollinators.info podcast episode 5. This was an interview with Dr. Ted Fleming who was talking with me about lesser long-nosed bats and pollination of saguaro cacti, and their use of hummingbird feeders in Tucson, Arizona [US]. If you'd like to learn more about pollinators, just visit www.pollinators.info. And if you'd like to keep up with all the latest from pollinators.info,

subscribe to the free weekly email newsletter. You'll also get discounts on upcoming product releases, a free e-booklet about killer bees, and several other goodies that you can look forward to. So, thanks again, take care, and listen in next time!

Podcast Episode 6: Interview with Dr. Robbin Thorp

Quick Glossary of science terms that aren't explained in this podcast:

- Endemic: lives only in one area
- Forage: the act of searching for and collecting food
- APHIS: Animal and Plant Health Inspection Service
- Markers: genetic markers are like the signature of a particular organism
- Microsporidian: a unicellular, spore-forming, fungal parasite

Athena (ARA): Hi there! I'm Athena, the author of pollinators.info, and you're listening to podcast episode 6. This is an interview with Dr. Robbin Thorp, and he's going to be talking with me about his research with the critically endangered Franklin's bumble bee, also known as *Bombus franklini*.

Well, thanks so much for joining me today to talk about the Franklin's bumble bee!

Dr. Robbin Thorp (RT): Ok!

ARA: So, let's give everybody an idea about what you do- so, could you describe your job for people?

RT: My job... well, I'm retired!

ARA: Well, there you go!

RT: (Laughs) But I'm still active in research. And Franklin's bumble bee is one of the projects I got into in my retirement career. I've always been interested in bumble bees, but this is an opportunity that came along and I've really delved into it. And it's gone in a very different direction from what I had originally started.

ARA: And how's that?

RT: Well, Franklin's bumble bee has a very, very narrow distribution. It occurs only in portions of southern Oregon and northern California, in an area about 190 miles

long and about 70 miles wide. And that's one of the narrowest distributions of any of the bumble bees in the world, that we're aware of.

A colleague from the [US] Forest Service posed the question to me as to whether this species should be listed [as endangered], because it's such a narrow endemic. And, so I set out to find out more about it. It had been put on a [list of] candidate species for endangered species listing when the Act was first enacted, because of its narrow distribution. We just didn't have enough information on it biologically to know how its populations were doing and much about it.

I had made some excursions into the area in the late '60s to look at and look for the bee, and found it then. So, in '98 I began a monitoring program, trying to find the bee and the plan was to see what I could find about its habitat requirements; why is it so restricted? It has a very close relative, the western bumble bee, that's a very widespread thing, and overlaps with it. But here Franklin's bumble bee stays in this very, very narrow range, and yet, within that range, it lives in a variety of different elevation habitats- all the way from 500ft elevation, on up to 6700ft elevation. So, with that kind of range in elevation, why hasn't it gotten out of the area where it exists, and gone into other areas?

So, those were the questions I set out to look at. The first year, I could find them everywhere. I looked at all the historic sites, all the sites we had from museum records, where we knew that the bee occurred. And, I found them virtually everywhere I looked, and even extended the range about 10 miles North and another 10 miles or so to the Southwest, but still within the geographic range that it had previously existed in.

ARA: Right.

RT: So, it occurs in between the crest of the Sierra-Cascade Range and the Coast Ranges, and South of the Willamette Valley down into California to the Marble Mountain Wilderness, in the Trinity Alps, and then Mount Shasta. And, it seems to be

affiliated with major drainages of the Umpqua, the Klamath, and the Rogue River basins. But, other than that, it's a little bit hard to figure.

Bumble bees are mostly generalists; they forage on a wide variety of flowers. They're not limited to a specific kind of flower that might also be endangered. So, there didn't seem to be any reason there- so I did my best to try to compile a list of the flowers that it used for pollen and nectar resources. And they were pretty much the same as those of the western bumble bee [*Bombus occidentalis*], which occurs all the way from central California to Alaska and down the Rocky mountains to New Mexico and Arizona. So, it has a huge range, [and] lots of color variation, whereas Franklin's bumble bee is a very uniform color pattern.

So, it's still an enigma. But, during this monitoring process, the first couple of years- '98 and '99- I could find the bees pretty readily every day that I went out to look for them. But, shortly after that they began to be more and more difficult to find, and as I began to graph this stuff, it was clear that these things were really declining very rapidly. And, the same was true of the western bumble bee; so here's a very widespread thing that was also disappearing in the same area.

So, about 2003 or so I contacted a colleague up at Humboldt State [and] he was noticing that it went missing too. [We] put together a letter and submitted it to the Bumble Bee List, and asked if anybody else had noticed this decline, particularly of the western bumble bee. And, it looked like, from the responses we got, that it had pretty well disappeared from central California to southern British Columbia. In other parts of its range, the western bumble bee still seemed to persist. It wasn't clear whether it was declining or not, but at least it was persisting in those areas during that time.

ARA: Right.

RT: So, here we had these two very closely related species disappearing, and yet other bumble bees were doing just fine in these same areas. So, that really put

another puzzle into the equation, and wondering why just these two bumble bees should be declining; one [with] a very narrow range and one [with] a very broad range.

So, it didn't look like the standard kinds of things that are responsible for bumble bee declines in most areas; things like habitat conversion, pesticides, or a variety of other habitat changes, particularly habitat degradation. Because the habitats themselves, where Franklin's bumble bee in particular occurred, were not changing that drastically during that period, at least as far as I could perceive.

ARA: Yeah. Weird.

RT: Yeah! So, I did a little bit of investigating, and it turns out that, you know, this looks very much like a disease, or something quite specific to this particular group of bumble bees from this one little branch of the family tree. And, it turns out that, in the early '90s, there was a three-year window in which companies that were trying to commercialize bumble bees for greenhouse pollination wanted to bring in the European bumble bee, *Bombus terrestris*, which was being cultivated at that time. Well, APHIS, the branch of the USDA that controls introductions and things, said no, very wisely so. [And] several of us had recommended that, you know, we have plenty of local species, and those could be reared and used for commercial pollination.

Well, that got started- in the East they started rearing with *Bombus impatiens*, the eastern bumble bee. And, we needed something in the West, because the eastern bumble bee is not native out here either. So, I had suggested the western bumble bee to some colleagues here, so they brought the technology in from the European bumble bee rearers and applied it to the western bumble bee and, sure enough, they were able to produce colonies. And, for several years, the western bumble bee was used in greenhouses in the West, and *Bombus impatiens* in greenhouses in the East.

But there was one company that didn't have local facilities for rearing, so the idea that they wanted to do was to collect queens from here, ship them to Europe, to be

reared in facilities there, and then the colonies shipped back here for use in greenhouses and so on. So, that was allowed for a period of 3 years. Several of us had objected to it, and written some letters to APHIS, and we had quite a long discussion with them during that period, and finally it was stopped in '94. But there was a 3-year window in which our bumble bee queens were shipped to Europe, reared into colonies, and then shipped back here.

Well, they were being reared in facilities where the European bumble bee had been reared, and my hypothesis is that they picked up internal diseases, pathogens, from these rearing facilities, and those were brought back here. And, some of our bumble bees were particularly susceptible to that pathogen or pathogens that were accidentally introduced in this process. So, that's kind of the working hypothesis now, and [we're] trying to find ways to test this to see if, indeed, that is the cause.

ARA: Wow, that's interesting. So, do you do a survey for it every year?

RT: Oh yeah. I go up anywhere from 3-5 times a year, and spend several days in the area, searching for these bumble bees. It's a lot of field work, but it takes me to some pretty nice venues, like Mount Ashland, and Mount Shasta, and from my site on Mount Ashland, I get a gorgeous view of Mount Shasta on a clear day, so yeah, it's rough work, but somebody's got to do it.

ARA: (Laughs) So, is that what you like most about the work, is being outside and the views?

RT: Oh yeah. My son joined me one time up on Mount Ashland to help me by taking some photographs of things, and he looked around and he says, "Boy, this is a great outdoor office!" (Laughs) That's the way I tend to refer to it now myself. A bad day in the field is better than a good day in the office anytime!

ARA: (Laughs) Yeah, so that leads me to the next question- what are some particular challenges involved with this work?

RT: Well, you know, just the time and travel to get to the field sites, the constant searching, the fact that there are a lot of other bumble bees out there that look very similar, so you've got to look closely at these things. What I do is kind of wander through flower patches and look and count the bumble bees that are visiting these different kinds of flowers, and try to sort out and keep in mind the search image for Franklin's, in contrast to the much more common bumble bees that we have in the area. Because they do superficially look like it, you've got to look pretty closely at these things.

There is one project that's going on, a USDA-sponsored project, of which I'm a collaborator, with Sydney Cameron at the University of Illinois, and Jeff Lozier, who is now on the faculty at the University of Alabama. And, Sydney and Jeff are looking at the genetics of bumble bees; they've found some markers that will allow them to detect the primary pathogen that we think may be involved with this, and that's an organism that's called a microsporidian. It's genus *Nosema*, and *Nosema bombi* is known from bumble bees around the world. It probably has more than one strain, may actually be more than one species, but it's been worked on a lot.

We know there's some variation as far as bumble bee responses to it, and its responses to different bumble bees as hosts. But, anyway, the signatures can be detected in museum specimens, so we're now gathering together specimens from as far back as 1985, and looking for *Nosema* that may have been here prior to 1992 and then also looking at specimens since '92, to see whether there are different *Nosema* patterns or not. And that would be a pretty good test of this hypothesis. We just don't know enough about our native bumble bee diseases, but this is one genetic approach that should give us a handle on this kind of thing.

ARA: Is *Nosema* native to North America?

RT: Well, that's the question! There may be a native *Nosema* here. It is present- we are finding it in other bumble bees now, in recent surveys. But, we don't know

enough about the historic occurrence of it, nor do we know enough about the genetic patterns as to whether what we're seeing today is the result of introductions from this commercial trafficking in bumble bees, or whether the *Nosema* was here prior to that and whether it was a different *Nosema* strain or not. So, those are the kinds of things we're trying to look at.

ARA: Right. Let's give people a take-home message here. Someone who lives in Florida might be wondering, "Why should I care about a bumble bee in California?" So, what would you tell someone who asks you that? What are the broader impacts of this research, and the fact that this bumble bee might be going extinct?

RT: Well, bumble bees are part of the larger ecosystem. They certainly contribute to pollination of native plants, and in keeping native ecosystems together. And, although it may not directly impact somebody in Florida, whether it goes missing or not, but the causes of this are things that will alert us to strategies of, "How do we prevent this kind of thing in the future?"

ARA: Right, and if people like tomatoes, the kind that are grown in a greenhouse, it'd be harder to get a hold of them without the bumble bees. So, what would you recommend for someone who tells you that they want to help conserve bumble bees and other pollinators?

RT: Well, there are a number of things. Bumble bees need food, so gardeners are a great resource for plantings. Bumble bees do occur in urban areas, because there are a wide variety of flowers that gardeners plant that still do have resources in them. A lot of horticultural varieties aren't much use to bees because the reproductive parts are not there. So, pollen and nectar are not necessarily available in, let's say roses, where you've got all those compound petals. Those petals are produced at the expense of anthers that produce pollen. So, if you've got a very showy, multi-petaled rose, bees are going to ignore that flower because it has no resources for them. But, if you plant some

heirloom roses, that are much simpler and have anthers, those will produce pollen for bees.

The other thing bees need is nest sites. Bumble bees tend to nest mostly underground, in cavities that are formed by burrowing rodents, like pocket gophers. Artificial boxes can [also] be set out. Usually they like an underground entrance, [and] they need some kind of nesting material in the box. Things like upholsterers cotton [not polyester] is probably the best. Not medicinal cotton because it's too fibrous and the bumble bees kind of get hung up in that.

ARA: Mmm-hmm. Do you have any final thoughts you'd like to add about anything?

RT: Bumble bees are beautiful! (Laughs)

ARA: (Laughs) Well, Dr. Thorp, thank you so much for your time today!

RT: Well, I enjoyed talking with you.

ARA: Thanks again for listening. This has been pollinators.info podcast episode 6. I'm Athena, the author of pollinators.info, and I was talking with Dr. Robbin Thorp about his research on the critically endangered Franklin's bumble bee. Learn more about bumble bees, other native bees, and all kinds of pollinators all over the world by visiting www.pollinators.info. You can also get all kinds of fun free stuff and discounts on product releases when you sign up for the free weekly email newsletter. So, stop by pollinators.info for all your pollination needs, and let me know if there's anything you don't see on the site that you'd like me to feature in the future. Thanks again for listening, stay tuned for next month's podcast, and take care!