Bee Attraction Literature Review

Feeder color/pattern

General Conclusions

- Bees do tend to have innate preferences for the blue-violet range
- BUT learned behaviors based on local pollen sources will often overrule the innate preferences, so the ideal feeder color may be dependent upon nearby wildlife to the testing site
    - Learned preference varies between species and location - most often blue, purple, or yellow
- Bees are more attracted to a larger floral display size
- Bees have trichromatic color vision

Adaptation, Genetic Drift, Pleiotropy, and History in the Evolution of Bee Foraging Behavior

- Overview: This is actually a chapter of a book about animal behavior. This chapter examines the behavior of bees in terms of flower constancy, floral color preference, learning behavior, traplining, and communication about food sources. They reference several experiments and studies to promote their conclusions in each of these categories.
- Key takeaways/useful info:
    - Tested the color preferences of eight bumblebee species from three subgenera: four species from central Europe (B. terrestris, B. lucorum (L.), B. pratorum (L.), and B. lapidarius); three from temperate East Asia (Bombus diversus (Smith), Bombus ignitus (Smith), and Bombus hypocrita (Pérez)); and one from North America (Bombus occidentalis (Greene)).
    - All species tested preferred the violet–blue range
        - These were unlearned color preferences of lab-grown and young bees

Bees' subtle colour preferences: how bees respond to small changes in pigment concentration

- **https://link-springer-com.proxy2.cl.msu.edu/article/10.1007/s00114-013-1060-3**
- Overview:
    - In this study, bees were trained with artificial flowers with a specific pigment concentration of either Acridine Orange or Aniline Blue. They were then given the simultaneous choice between three test colors with varying pigment concentrations. It was found that bees didn't usually prefer the "training" concentration or the highest pigmentation but **chose stimuli with the highest spectral purity (saturation) and highest contrast from the background**. Overall, this suggests that **bees choose an intermediate pigment concentration** due to its "optimal conspicuousness" and that bee preference for flowers with high spectral purity may actually "exert selective pressure on the evolution of floral colours and of flower pigmentation."
- Key takeaways/useful info:
    - Used trained honeybees and bumblebees, do not specify families or how many of each were used
    - Spectral purity (saturation) and pigment concentration are important cues for bees to detect and approach flowers
        - Bees were attracted to artificial flowers of high saturation (spectral purity)

    - The bumblebees could have been attracted to high spectral purity because the "detectability of flowers" may increase with pigment concentration.
        - High pigment concentration generally means high saturation?
    - In addition, colors produced by higher floral pigment concentration are perceptually more distinct and distant from background colours. If pigment concentration is associated with spectral purity, then it makes sense that floral pigment concentration may be correlated with the flowers' "detectability."
        - It is still unknown if pigment concentration can also act as honest flower signal indicating the amount of reward and if natural variability of actual plant species alter the behaviour of foraging bees

Color preferences of bees captured in pan traps

- https://go-gale-com.proxy1.cl.msu.edu/ps/i.do?p=AONE&u=msu_main&id=GALE|A499720979&v=2.1&it=r&sid=zotero&asid=021e95bf
- Overview:
    - This paper examines the color preferences of five bee families in Florida between yellow, blue, and white using pan traps. Two bee families, **Andrenidae and Halictidae, were shown to have an affinity for yellow, while Megachilidae and Apidae had a preference for blue**. Insufficient numbers of colletidae were collected for analysis.
- Key takeaways/useful info:
    - Results are split up by species - since the data was taken Florida, it may be useful to check which species are native to Michigan and base initial testing on those species' color preferences
        - **Andrenidae**, **Apidae**, Colletidae, **Halictidae**, **Megachilidae**, Melittidae
        - List is popular Michigan bee families, **bold** = included in study
        - Andrenidae - affinity for yellow
        - Halictidae - affinity for yellow
        - Megachilidae - affinity for blue
        - Apidae - affinity for blue
        - Insufficient numbers of colletidae were collected for analysis
    - "Several studies have compared bee captures between pan traps and nets and have demonstrated that pan traps alone do not accurately represent the species composition of bee populations"
        - They only did pan trap experiments so it might not be completely accurate - although pan traps seem closer to our feeding devices in general shape than a net so this is probably best anyways
    - A source of error to keep in mind for our own experiments: "Environmental factors at different locations could alter the ratio of captured bees, such as the presence of flora that would draw one species more than another away from the traps."

Floral traits influencing plant attractiveness to three bee species: Consequences for plant reproductive success

- https://bsapubs-onlinelibrary-wiley-com.proxy2.cl.msu.edu/doi/full/10.3732/ajb.1600405

- Overview: In this study, scientists contrasted the roles of floral display size and flower color in attracting three bee species and determined the relationships between plant attractiveness (number of pollinator visits) and seed set for each bee species.
- Key takeaways/useful info:
    - Despite innate preferences for flower colors, bees can learn to associate a flower color with nectar or pollen rewards, and, when nectar production correlation with flower color disappears in a population, bumble bees no longer indicate a preference for a flower color
    - Three different bee species: honey bee (Apis mellifera), common eastern bumble bee (Bombus impatiens), and alfalfa leafcutting bee (Megachile rotundata)
    - Inconsistent color results, but a few general trends
        - "Based on the 2015 results, bumble bees more frequently visited plants with larger floral displays and purple flowers or flowers less distinct from the background foliage."
        - Leafcutting bees preferred purple (significant in ½ years)
        - Honey bees significantly disliked yellow in 2014 and significantly liked Endler purple in 2015
        - Yellow and white received far fewer visitors in general
    - Floral display size: larger is definitely better

Mechanisms, functions and ecology of colour vision in the honeybee

- https://link-springer-com.proxy2.cl.msu.edu/article/10.1007/s00359-014-0915-1
- Key takeaways/useful info:
    - Bees have three spectral types of photoreceptors peaking in UV, blue and green parts of the spectrum
        - S (short-wavelength sensitive, λ max = 344 nm), M (middle-wavelength sensitive, λ max = 436 nm), and L (long-wavelength sensitive; λ max = 544 nm) receptors
        - Trichromatic color vision
        - Shares basic similarities with human/primate color vision, but with a visual range that is shifted towards shorter wavelengths
    - Many different methods for modeling color discrimination in honeybees (see table 1)
        - Lots of discrepancies between these models (ex: effect of dim vs bright colors)
    - Color preferences/color learning
        - After a single color–sucrose pairing, in the case of blue-violet colours (e.g. 413, 428 nm), bees already responded very strongly to the training color in unrewarded tests, forming memories that could last up to 6 days
        - Other colors, particularly blue-green (e.g. 494 nm) required very few pairings before they were thoroughly discriminated and long-term memories were formed.
        - Spontaneous preference for targets reflecting in the short-wavelength range around 410 nm (blue-violet)
            - but color learning processes very quickly override these tendencies and dominate color choice

Shape preference in bees: innate preference for flower-like patterns

- Overview: This study examined bees' innate preferences towards various black and white patterns displayed on vertical surfaces. They found that bees express a positive preference towards radiating elements with lower frequencies of repetition. Symmetrical patterns were more attractive than non-symmetrical patterns.
- Key takeaways/useful info:
    - Bees were initially trained to collect a reward from a checkerboard pattern, then exposed to different patterns
    - Conclusions support the idea that bees have an innate preference for flower-like patterns

Feed content

General Conclusions

- Bees prefer low viscosity, high sucrose concentration, and warm nectar

Foraging bumblebees acquire a preference for neonicotinoid-treated food with prolonged exposure

- https://royalsocietypublishing-org.proxy2.cl.msu.edu/doi/pdf/10.1098%2Frspb.2018.0655
- Overview: The purpose of this study was to examine how bees' risk of exposure to neonicotinoids may change over time by observing behavioral changes in the bees, unlike the majority of experiments testing the impact of neonicotinoids. They exposed bees to an array of sucrose feeders containing 0, 2 and 11 parts per billion of the neonicotinoid pesticide thiamethoxam. They found the proportion of visits to pesticide-laced feeders increased over time relative to untreated sucrose feeders, even when the feeders' location was altered. This indicates not only that bees have a preference for neonicotinoid-laced solution but that they can detect thiamethoxam and alter their behavior to continue feeding on it
- Key takeaways/useful info:
    - 0, 2 and 11 parts per billion of thiamethoxam is said to "closely mimic pesticide exposure in the wild" - does this match up with the data other groups have found?
    - "A recent electrophysiological study showed that honeybees and bumblebees are unable to taste three major neonicotinoids (clothianidin, imidacloprid and thiamethoxam) through their proboscis. However, the same study showed that isolated bees consumed a higher total amount of pesticide-laced sucrose solution containing either imidacloprid or thiamethoxam than untreated sucrose solution in a two-choice feeding assay over 24 h"
        - Bees have an affinity for neonicotinoids, but we're still not really sure how
    - Single or short-term acute exposure to neonics is be rare in the wild
    - Measured the volume of sucrose consumed and the proportion of visits to each concentration - similar to our procedure for the different feeding devices
    - one feeder in each row of feeders was randomly assigned to each of the three concentrations
        - found no effect of changing the arrangement of the feeders between the first (Period 1) and second (Period 2) half of the experiment on feeding rate
        - However, their experiments were in a very controlled and uniform environment while ours will be outdoors, so randomization will be important

    - cleaned the feeders first with 70% ethanol and then water to remove any neonicotinoid residues or scent cues

Nectar source profitability influences individual foraging preferences for pollen and pollen-foraging activity of honeybee colonies

- https://link-springer-com.proxy2.cl.msu.edu/content/pdf/10.1007/s00265-019-2644-5.pdf
- Overview: This paper studied how the profitability of nectar sources influences the transition of bees between nectar and pollen collection at the individual response level by measuring the number of switches when the nectar source was at a higher or lower sucrose concentration.
- Key takeaways/useful info:
    - Bees preferred the nectar more when it was a higher sucrose concentration (~50% w/w) than when it was a lower concentration (~3% w/w)

Honeybees prefer warmer and more viscous nectar, regardless of sugar concentration

- https://www-jstor-org.proxy2.cl.msu.edu/stable/23478830?pq-origsite=summon&seq=1#metadata_info_tab_contents
- Overview: In this study, the experimenters tested the response of *Apis mellifera scutellata* (10 colonies) to 10% and 20% sucrose solutions at varying temperatures and viscosities. The honeybees preferred lower viscosity and higher temperature nectar at both sucrose concentrations. In addition, honeybees tended to avoid the high viscosity and low temperature nectars even more upon successive visits.
- Key takeaways/useful info:
    - May be because internal temperature of certain flowers is a few degrees warmer than air temperature
    - Higher viscosity nectar requires more energy expenditure to intake

Scent (feeder or nectar)

General Conclusions

- There are definitely a lot of scents secreted by flowers that attract bees for pollination
- Most of the scents I've found are pretty specific to certain bee/flower species
- A lot of the "real-world application" experiments have been unsuccessful - I haven't found a single experiment with solid evidence that a scent resulted in a significant pollination increase in natural environmental conditions

1,4-Dimethoxybenzene, a Floral Scent Compound in Willows that Attracts an Oligolectic Bee

- https://link-springer-com.proxy2.cl.msu.edu/article/10.1007%2Fs10886-005-9152-y
- Overview: In this study, they identified flower scent compounds of two Salix species important for the attraction of the oligolectic bee *Andrena vaga*, which collects pollen only from Salix. The antennae of male and female bees responded to at least 16 compounds, among them different benzenoids as well as oxygenated monoterpenoids and sesquiterpenoids.
- Key takeaways/useful info:
    - Oligolectic: collect pollen for their larvae only from one particular plant family or genus
        - True for many bees
    - The strongest antennal responses were triggered by 1,4-dimethoxybenzene

A key floral scent component (β-trans-bergamotene) drives pollinator preferences independently of pollen rewards in seep monkeyflower

- https://besjournals-onlinelibrary-wiley-com.proxy2.cl.msu.edu/doi/full/10.1111/1365-2435.13246
- Overview: "We examined the floral scent profile of seep monkeyflower, a bumble bee pollinated herb that offers only pollen as a reward to pollinators. We also tested bumble bee preferences for different floral scent profiles. We found that six compounds were emitted in quantities that were positively correlated with pollen reward quality, potentially providing honest signals of pollen reward status. However, when given scents from flowers offering different levels of pollen rewards, bumble bees with prior foraging experience on seep monkeyflower did not exhibit any preferences for scents based on pollen reward quality. On the other hand, bumble bees without prior foraging experience were strongly attracted to β-trans-bergamotene, a compound that was produced in high quantities but was not correlated with pollen reward quality."
- Key takeaways/useful info:
    - The volatile emissions of M. guttatus provide reliable indicators of pollen rewards (potential honest signals), but that the preference of bumblebees for outbred plants is not driven by these cues but rather by a sensory bias for β-trans-bergamotene
    - Demonstrates that "uninformative" compounds are key to attracting pollinators to a rewarding plant species
- Related links
    - Profile of chemical compound: https://pubchem.ncbi.nlm.nih.gov/compound/trans-beta-Bergamotene#section=Related-Substances

An evaluation of Fruit-Boost™ as an aid for honey bee pollination under conditions of competing bloom

- https://www-tandfonline-com.proxy2.cl.msu.edu/doi/abs/10.3896/IBRA.1.48.1.04
- Overview: The honey bee attractant Fruit Boost™ was tested for its efficacy in focusing honey bees onto the target crop (watermelon) and improving pollination. Fruit Boost did not significantly affect the total number of honey bees visiting watermelon flowers, the proportion of honey bee visits that occurred on female flowers, fruit-set, or fruit weight.
    - Didn't work

Appetitive behavior of the honey bee Apis mellifera in response to phenolic compounds naturally found in nectars

- https://jeb-biologists-org.proxy2.cl.msu.edu/content/222/2/jeb189910#ref-45
- Overview: The goal was to find out differences between the compounds found in onion nectar, in terms of not only their palatability but also their effect on bee sensory and cognitive abilities.
- Key takeaways/useful info:
    - In a previous study - the higher number of bee visits and, as a consequence, the higher seed yield in OP lines may be due to the presence of luteolin (7.2 mg l−1). In contrast, a line that had a high naringenin and quercetin content (MSL1, 8.0 and 1.0 mg l−1, respectively) showed the least number of bee visits.
    - The chemical compounds used to prepare the different treatments (see Table 1) were luteolin, quercetin, naringenin and potassium

    - In this study, however, they found no significant differences in the percentage of bees responding to the nectar with different chemical compounds or in the volume of nectar consumed.

Evaluation of Nasonov Pheromone Dispensers for Pollinator Attraction in Apple, Blueberry, and Cherry

- https://search-proquest-com.proxy2.cl.msu.edu/docview/2217571413?pq-origsite=summon
- Overview: "In this study, we evaluate two new pollinator attractants, Polynate and SPLAT Bloom, for their ability to increase pollinator visitation and fruit set in apple (Malus pumila Mill.), highbush blueberry (Vaccinium sp. L.), and tart cherry (Prunus cerasus L.). Polynate is a plastic twintube dispenser loaded with a mixture of floral scent and Nasonov pheromone. SPLAT Bloom contains the same chemical formula as Polynate, but is applied as a 3 g wax dollop directly onto the tree or bush."
- Key takeaways/useful info:
    - conducted replicated evaluations of 32 fields or orchards with and without putative attractants over three growing seasons. Both products failed to provide a measurable increase in pollinator visits or fruit set in these crops, indicating no return on investment for either product.
    - Basically it didn't work

Nectar Attracts Foraging Honey Bees with Components of Their Queen Pheromones

- https://link-springer-com.proxy2.cl.msu.edu/article/10.1007/s10886-015-0642-2
- Overview: Freely foraging bees preferred solutions with honeybee queen mandibular pheromone (QMP) components to control solutions, and QMP components over-rode or reversed avoidance of cholorogenic acid (CA) and isocholorogenic acid(IA). Furthermore, prior exposure to the presence or just the odor of QMP components removed the deterrent effects of CA and IA. By mimicking the honey bee pheromone blend, nectar may maintain pollinator attraction in spite of deterrent nectar compounds.

Other helpful sources

Insect identifier for Michigan

- https://www.insectidentification.org/insects-by-type-and-region.asp?thisState=michigan&thisType=Bee,%20Ant,%20Wasp%20and%20Similar
- Could be helpful in identifying the types of bugs in our feeders

List of bee families in Michigan

- https://www.canr.msu.edu/uploads/234/74792/Gibbs_-_Master_Gardener_Smaller.pdf
- Slide 28
- Andrenidae (e.g., miner bees), Apidae (e.g., honey bees, bumble bees, carpenter bees, squash bees), Colletidae (e.g., cellophane bees), Halictidae (sweat bees), Megachilidae (e.g., leaf-cutter bees, mason bees), Melittidae (oil-collecting bees)

Possible variables

Color

- Blue vs violet vs white vs yellow vs green
- Pigment concentration/saturation

Shape/Design Elements (Floral display)

- “Floral display” types vs control (no floral display)
    - Various patterns
- Floral display size

Feed Elements

- Sucrose concentration
- Viscosity?
    - Study used Tylose H 10000 P2
    - Datasheet: https://www.essentialingredients.com/spec/Tylose%20H%2010000%20P2.pdf