

Quantifying Nectar Resources in Bumble Bee Visited Plants

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Abstract

Native bumble bees play key roles in their ecosystems as pollinators, but little is known about the quantity and quality of floral resources on which they depend in natural areas across a season. Additionally, how those resources might be affected by abiotic factors, many of which are being altered under climate change, is poorly understood. To address this knowledge gap, we quantified nectar resources for bumble bee visited plant species in subalpine meadows. Specifically, we (1) examined interspecific variation in nectar resources, (2) compared nectar resources across wet and dry meadow conditions, and (3) examined intraspecific variation in nectar resources between years. Nectar volume, sugar concentration, and sugar content (“nectar traits”) were variable across species, within species, and in response to both local and annual water availability. This research clarifies the relative contributions of plant species to the resource landscape available for bumble bees, and how this resource landscape may respond to variation in abiotic conditions.

Introduction

Native bumble bees are important pollinators, and play key roles in the function of their ecosystems (reviewed in Ogilvie et al., 2017). Bees depend exclusively upon flowers for their nutritional needs—adult bees subsist on nectar from flowers and feed floral pollen and nectar to their developing larvae (Willmer, 2011). However, we know very little about the quantity and quality of these resources and their distribution in natural landscapes, including how they are influenced by abiotic factors. An understanding of how the floral resource landscape changes with variation in abiotic factors is increasingly important for predicting potential impacts on bees as those factors are being altered under climate change (IPCC, 2013). Here, we quantified floral nectar resource availability in bumble bee visited plant species, then compared how those resources vary with natural variation in water availability. Specifically, we (1) quantified variation in nectar volume, concentration, and sugar content (“nectar traits”) across species in abundant bumble bee visited plants; (2) compared nectar traits in dry and wet meadow habitats, both within individual species and for the resources provided by the meadows as a whole; and (3) compared nectar traits between a dry, early-snowmelt year (2018) and a wet, late-snowmelt year (2019), within individual species.

In dry conditions (i.e., dry habitats and drought years), water availability may limit the amount of water allocated to nectar production, thus limiting nectar volume and potentially increasing the nectar sugar concentration, depending on whether the plants have a mechanism for moderating their nectar concentration (eg. Phillips et al., 2018). Dry conditions may additionally place stress on the plants that could reduce the amount of sugar they are able to allocate to nectar, thereby decreasing nectar sugar concentration (eg. Waser and Price, 2016; Descamps et al., 2018). In contrast, under wet conditions these limitations are likely to be released, and higher volumes and greater sugar concentrations may be expected.

Understanding the influence of water availability on nectar sugar concentrations is important for predicting the quality of resources available to bees. This work also provides relevant

background to ask future questions about bumble bee flower preferences and whether they align with the nutritional quality of the resources provided. A greater understanding of the relative nutritional contributions of different plant species could also be useful in targeting conservation efforts (Vaudo et al., 2015; Woodard and Jha 2017).

Methods

Study site description

This work was conducted around the Rocky Mountain Biological Laboratory (RMBL), in Gothic, Colorado, USA (38°57.5'N, 106°59.3'W). This high elevation ecosystem (2891 m above sea level in the Gothic townsite) is surrounded by aspen and conifer forests and dry and wet meadow habitats (Langenheim, 1962). The plants used by bumble bees in these habitats are almost entirely native to the area; with the exception of *Taraxacum officinale*, *Trifolium pratense*, and *Trifolium repens*; meaning that bees have been using these resources in these environments for a very long time. The RMBL has established floral and bumble bee surveys, as well as a long-term weather data set, that allows for extrapolation from relatively short-term nectar collection to estimate patterns of resource availability over time and space, as well as the potential to compare aspects of nectar quality with bumble bee usage.

Nectar collection and quantification

I collected nectar from bumble bee visited plant species (Jane Ogilvie and Justin Bain, *unpublished data*), within subalpine meadows at six study sites near the Rocky Mountain Biological Laboratory. The plant species sampled were *Aconitum columbianum*, *Adenolinum lewisii*, *Claytonia lanceolata*, *Delphinium barbeyi*, *Delphinium nuttallianum*, *Erigeron flagellaris*, *Erigeron speciosus*, *Erythronium grandiflorum*, *Frasera speciosa*, *Helianthella quinquinervis*, *Heliomeris multiflora*, *Heterotheca villosa*, *Hydrophyllum capitatum*, *Hydrophyllum fendleri*, *Ipomopsis aggregata*, *Lathyrus leucanthus*, *Mertensia ciliata*, *Mertensia fusiformis*, *Potentilla pulcherrima*, *Salix* spp., *Taraxacum officinale*, *Vicia americana*, and *Viola praemorsa*. Nectar data for *Chamaenerion angustifolium* from 2018 was also included in interspecies comparisons. Nectar was collected using 1, 2, 5 or 10 µl Drummond brand microcapillary tubes. For species with florets too small to fit a microcapillary tube (*E. flagellaris*, *E. speciosus*, *H. multiflora*, and *H. villosa*) or with nectar spread too thinly (*P. pulcherrima*), a nectar droplet was obtained by centrifuging the flower heads for one minute at 5000 rpm (*E. speciosus* and *E. flagellaris*) or 3000 rpm (*H. multiflora*, *H. villosa*, and *P. pulcherrima*). This droplet was then collected with a microcapillary tube, as in the other flowers.

The nectar volume was determined by measuring the proportion of the microcapillary tube that is filled and multiplying by the total volume the tube could contain. Nectar sugar concentration in degrees Brix was then determined using a hand refractometer (Eclipse low-volume and No. 11654 0~92%) and converted to sugar content as described in Hicks et al. (2016). Plants were

covered with pollinator exclusion bags (Midco Pollination Seed Hybridization Bags, 366 micro pore diameter, and sand-based mesh bags) for 12 to 24 hours (with one exception at 48 hours) prior to nectar collection to prevent depletion of nectar stores. Samples thus included the standing crop of nectar plus the accumulation while bagged. Air temperatures did not differ between the inside and outside of the pollinator exclusion bags (Figure S1; $T = -0.58478$, $P = 0.5605$). Samples were taken per flower, stalk, or bag, depending on the species, as necessary to acquire enough volume of nectar to get a clear refractometer reading (approximately 0.06µl in bright light conditions). The total number of flowers sampled and the number of flowers with nectar were recorded. For each species, we took nectar samples over a minimum of two separate sampling days, getting a minimum of fifteen total nectar sugar concentration readings (except for following species: *Adenolinum lewisii*, *Heliomeris multiflora*, *Salix* spp., *Viola praemorsa*. Volume $N = 10, 10, 14, 10$. Nectar sugar concentration $N = 3, 10, 4, 4$). For species that exist in both dry and wet meadow habitats, we took a minimum of fifteen nectar sugar concentration readings per meadow type (dry and wet).

Floral resource quantification

We quantified floral abundance available to bees at six study sites established by Jane Ogilvie, spaced ~1 km apart through the East River valley (Figure 1). Bumble bee activity and floral resources have been continuously monitored at these study sites since 2015. Each site contains transects representing three habitats (dry meadow, wet meadow, and aspen forest), totalling 100 x 0.5 m in each of the three habitats. We visited the sites weekly, beginning on 1 June in 2019 (shortly after snowmelt), to count the open flowers of bee-visited species within each transect.

Data analysis

All of the following analyses were conducted for each nectar volume, sugar concentration, and sugar content. All statistics were conducted in the R statistical computing framework (R Core Team, 2018). An ANOVA testing the effect of species on nectar traits was used to consider interspecific nectar trait variation.

In order to examine differences between nectar resources provided by wet and dry meadows as a whole, nectar trait values were scaled by the mean number of open flowers of each species for which we have nectar data, per transect, in each habitat type, across sites. These values were then compared using a Wilcox rank sum test. These scaled values were also split by the week of floral count, and an ANOVA was used to examine the effect of habitat type and of habitat type * week interaction.

In order to examine intraspecific differences between wet and dry meadow habitats, a Wilcox rank sum test was used to compare nectar traits for species measured in both habitats (*Claytonia lanceolata*, *Delphinium nuttallianum*, and *Taraxacum officinale*).

Intraspecific differences between 2018 (an early-snowmelt, dry year) and 2019 (a late-snowmelt, wet year) were examined with a Wilcoxon rank sum test for species measured in both years (*Aconitum columbianum*, *Delphinium barbeyi*, *Delphinium nuttallianum*, *Erigeron flagellaris*, *Helianthella quinquinervis*, *Ipomopsis aggregata*, *Lathyrus leucanthus*, *Mertensia ciliata*, and *Vicia americana*; Water accumulation 1 May through 9 Aug: 2018, 7.75 cm; 2019, 17.27 cm. Weather data courtesy of Billy Barr.). Nectar trait values for 2018 were provided by Murphy, Bain, and CaraDonna.

Results

Interspecific nectar trait variation

Nectar volume, sugar concentration, and total sugar content per flower were variable across species, with *F. speciosa* having significantly higher volumes and sugar contents than the other species (Figures 2-4; ANOVA (main effect of species): $F = 66.35$, $P < 0.0001$; $F = 23.31$, $P < 0.0001$; $F = 58.98$, $P < 0.0001$).

Intraspecific nectar trait variation

The majority of species sampled showed a right-skewed intraspecific distribution of nectar volumes, in which most flowers did not have any nectar, a small number had small to moderate amounts, and very few had much higher quantities. The flowers with the highest volumes often produced approximately four times as much nectar as was provided by those with low volumes (Figure 5).

Dry versus wet meadow habitats: whole meadows

The mean nectar volumes, concentration, and sugar contents per transect were higher in wet meadows compared to dry meadows, (Figures 6-8; Wilcoxon Rank Sum Test: $W = 43504$, $P < 0.001$; $W = 23795$, $P < 0.001$; $W = 21804$, $P < 0.001$).

When the data was split by the week of the floral count, the dry meadows initially had higher nectar volumes, concentrations, and sugar contents compared to wet meadows. Nectar traits were similar in the two meadow types through much of the early to mid summer. Over the last few weeks of counts, the wet meadows had higher nectar volumes, concentrations, and sugar contents compared to dry meadows. (Figures 9-11; ANOVA: volume: main effect of site type, $F = 9.759$, $P < 0.001$; site type x week interaction, $F = 3.749$, $P = 0.053$; concentration: main effect of site type, $F = 0.566$, $P = 0.452$; site type x week interaction, $F = 9.950$, $P = 0.002$; sugar content: main effect of site type, $F = 7.243$, $P = 0.007$; site type x week interaction, $F = 3.126$, $P = 0.078$).

Dry versus wet meadow habitats: intraspecific

For species sampled in both wet and dry meadows, we found that nectar volumes were higher in the wet meadows for *C. lanceolata* and lower in wet meadows for *D. nuttallianum* compared to the dry meadows (Figure 12 a, d ; Wilcoxon Rank Sum Test: $W = 61$, $P < 0.001$; $W = 807.5$, $P < 0.001$).

Volumes did not differ between meadow types for *T. officinale* (Figure 12 h; Wilcoxon Rank Sum Test: $W = 461.5$, $P = 0.168$). Nectar sugar concentrations were higher in the wet meadows for *T. officinale* and lower in the wet meadows for *C. lanceolata* and *D. nuttallianum*, compared to dry meadows (Figure 12 h, b, e; Wilcoxon Rank Sum Test: $W = 437.5$, $P < 0.001$; $W = 0$, $P < 0.001$; $W = 241$, $P = 0.007$).

Nectar sugar content was higher in wet meadows for *D. nuttallianum* and lower in wet meadows for *C. lanceolata* and *T. officinale* (Figure 12 f, c, i; Wilcoxon Rank Sum Test: $W = 679$, $P < 0.001$; $W = 3$, $P < 0.001$; $W = 356$, $P < 0.001$).

Intraspecific comparison of nectar traits between 2018 and 2019

For species sampled in both the dry year 2018 and the wet year 2019, we found that nectar volumes were higher in 2019 for *A. columbianum*, *D. nuttallianum*, *D. barbeyi*, *M. ciliata*, and *V. americana*, and lower for *I. aggregata* and *L. leucanthus* (Figure 13 a, d, g, s, v, m, p; Wilcoxon Rank Sum Test: $W = 197$, $P = 0.003$; $W = 114.5$, $P = 0.003$; $W = 997$, $P = 0.0503$; $W = 266.5$, $P < 0.001$; $W = 108.5$, $P < 0.001$; $W = 1394$, $P < 0.001$; $W = 464$, $P < 0.001$). Nectar volumes did not differ between years for *H. quinquinervis* (Figure 13 j; $W = 161.5$, $P = 0.1252$).

Nectar sugar concentrations were lower in 2019 for *D. barbeyi*, *D. nuttallianum*, *L. leucanthus*, *M. ciliata*, *V. americana*, and higher for *I. aggregata* (Figure 13 column 2 (e, h, q, t, w, n); Wilcoxon Rank Sum Test: $W = 1712$, $P < 0.001$; $W = 455$, $P < 0.001$; $W = 256$, $P < 0.001$; $W = 626$, $P = 0.009$; $W = 851$, $P < 0.001$; $W = 255$, $P < 0.001$). Nectar sugar concentrations did not differ between years for *A. columbianum* or *H. quinquinervis* (Figure 13 b, k; Wilcoxon Rank Sum Test: $W = 220.5$, $P = 0.076$; $W = 72$, $P = 0.645$).

Total sugar content per flower was higher in 2019 for *A. columbianum*, and *M. ciliata*, and lower for *H. quinquinervis*, *I. aggregata*, and *L. leucanthus* (Figure 13 column 3 c, u, l, o, r; Wilcoxon Rank Sum Test: $W = 83$, $P = 0.024$; $W = 181$, $P < 0.001$; $W = 102$, $P = 0.019$; $W = 899$, $P < 0.001$; $W = 216$, $P < 0.001$). Total sugar content did not differ for *D. barbeyi*, *D. nuttallianum*, or *V. americana* (Figure 13 f, i, x; $W = 1238.5$, $P = 0.473$; $W = 148$, $P = 0.082$; $W = 305$, $P = 0.068$).

Discussion

Our research begins to build a picture of the nectar landscape around RMBL, both across space and time. Floral distributions, inter- and intra-specific variation in nectar traits, and abiotic factors such as water availability all affect the resources that are available for bees. The interactions between these factors are complex, but we can begin to identify trends in relation to each.

We find that nectar traits are variable among species. There is also additional variation introduced by intraspecific variation, distributions of flowers throughout habitats, and likely by consumption and evaporation. This variation likely impacts the quality and accessibility of these nectar resources for bees, since the viscosity of nectar changes with concentration and only a certain range of concentrations are energetically worthwhile for bees to consume, since a trade-off exists between the energy obtained and the difficulty of consuming viscous nectar at higher sugar concentrations (Heyneman, 1983). *Frasera speciosa*'s high nectar volume and sugar content per flower is particularly interesting due to their mast seeding reproductive strategy (Taylor & Inouye, 1985). This combination seems to have the potential to dramatically change the nectar landscape in mast seeding years, such as 2019.

Most flower species sampled demonstrated a “jackpot” structure for their nectar volumes, where most flowers had no nectar, a few had small amounts, and very few had high quantities (the “jackpots”). This structure likely incentivizes bees to visit a greater number of flowers on more different individuals than they would if they encountered a constant low quantity of nectar in each, thereby improving the pollination services received by the flowers while minimizing the resources invested (Biernaskie, Cartar, & Hurly, 2002).

Wet and dry meadow types differed in all three of the nectar traits we considered. This is likely a combined effect of differences in floral abundances and intraspecific differences in nectar traits between wet and dry meadow habitats. We accounted for 64% of open flowers from surveys throughout the summer growing season with our nectar data. The shift from similar nectar trait values in both meadow habitats in the early summer to elevated values in wet meadows over dry later in the season, as the soil begins to visibly dry out in the dry meadows, suggests that soil moisture is likely an important predictor for nectar traits. Bumble bees also seem to respond to this shift in resource availability, beginning to primarily be found in the wet meadows just as the resources there increased in comparison to the dry meadows (Jane Ogilvie and Justin Bain, *personal observation*).

Differences in nectar traits between wet and dry meadows were also seen for individual species. This may be the result of water abundance, availability of other resources, competition, and stress. *Delphinium nuttallianum* and *T. officinale* both showed the general trends that we predicted, with wet meadows having higher nectar volumes and both higher (*T. officinale*) and

lower (*D. nuttallianum*) sugar concentrations, with higher sugar content, compared to the dry meadows. *C. lanceolata*'s lower nectar volume in the wet meadow, however, was contrary to our predictions, but may have been influenced by the greater time gap between sampling at dry and wet meadows. *C. lanceolata* was sampled in the dry meadow early in the season, when the dry meadows were still relatively wet from snowmelt, and sampled in the wet meadow almost a month later after drier conditions, so there may not have been a difference in soil moisture in the direction expected between the two habitats.

Nectar traits also varied between 2018 and 2019 for most species. Nectar volumes were lower in dry 2018 for most species, and nectar sugar content was also lower in 2018 for several species compared to wetter 2019. Differences in rainfall and early season water availability from snowmelt likely contributed to these differences, again suggesting that soil moisture might be a predictor for these traits. These annual differences suggest, as has been discussed before (eg. Phillips et al., 2018), that nectar may become a more scarce resource in areas for which drought is becoming more common, which could have strong negative impacts on the bee populations dependent upon those resources.

Overall, nectar has been variable in interesting ways, including among and within species and with differences in an abiotic factor (water availability). Variability is sometimes framed as detracting from the value of the study of nectar (eg. Willmer, 2011), but our research has suggested that the variation in nectar may be predictable, and both ecologically and evolutionarily valuable. Our results provide a basis for more rigorously understanding bumble bee resource use at both the population and community scales. Increasing our understanding of the factors contributing to the variation in nectar traits will be valuable as we attempt to predict and mitigate challenges facing pollinator populations, since the availability of nutritional resources is critical to the survival of a population.

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Figures

Figure Legends

Figure 1. Locations of floral count sites in the East River valley.

Figure 2. Species' nectar volumes (μl) in ascending order. Species are denoted by their four-letter

abbreviations (first two letters of the genus and first two letters of the epithet) Left to right: N = 10, 14, 33, 50, 17, 50, 57, 57, 21, 10, 71, 34, 20, 74, 63, 103, 47, 55, 27, 17, 77, 10, 27, 19. ANOVA (main effect of species): $F = 66.35$, $P < 0.001$. a. and b. differ in scale to show variation including and excluding *F. speciosa*.

Figure 3. Species' nectar sugar concentrations ($\text{mg}/\mu\text{l}$) in ascending order. Species are denoted by

their four-letter abbreviations (first two letters of the genus and first two letters of the epithet) Left to right: N = 4, 16, 25, 24, 73, 3, 17, 47, 42, 21, 60, 4, 10, 16, 101, 60, 37, 43, 39, 24, 18, 68, 24, 60. ANOVA (main effect of species): $F = 23.31$, $P < 0.001$.

Figure 4. Species' nectar sugar contents (mg) in ascending order. Species are denoted by their four-letter abbreviations (first two letters of the genus and first two letters of the epithet) Left to right: N = 3, 16, 4, 4, 16, 21, 24, 39, 60, 37, 43, 17, 73, 32, 60, 68, 24, 42, 101, 10, 25, 18. ANOVA (main effect of species): $F = 58.98$, $P < 0.001$. a. and b. differ in scale to show variation including and excluding *F. speciosa*.

Figure 5. Number of flowers with different nectar volumes by species, 2019. a. $N = 38$. b. $N = 38$. c. $N = 556$. d. $N = 42$. e. $N = 72$. f. $N = 31$. g. $N = 43$. h. $N = 19$. i. $N = 11$. j. $N = 11$. k. $N = 48$. l. $N = 276$. m. $N = 75$. n. $N = 118$. o. $N = 223$. p. $N = 74$. q. $N = 391$. r. $N = 31$. s. $N = 93$. t. $N = 63$. u. $N = 90$.

Figure 6. Mean nectar volume (μl) per transect in dry v. wet meadow habitats. Wilcoxon Rank Sum Test: $N = 388$, 577 , $W = 43504$, $P < 0.001$.

Figure 7. Mean nectar sugar concentration ($\text{mg}/\mu\text{l}$) in dry v. wet meadow habitats. Wilcoxon Rank Sum Test: $N = 482$, 326 , $W = 23795$, $P < 0.001$.

Figure 8. Mean sugar content (mg) per transect in dry v. wet meadow habitats. Wilcoxon Rank Sum

Test: $N = 482$, 577 ; $W = 21804$, $P < 0.001$.

Figure 9. Mean nectar volume (μl) per transect in dry v. wet meadow habitats by week. Week 1: $N = 3$, 2. Week 2: $N = 10$, 6. Week 3: $N = 20$, 16. Week 4: $N = 31$, 38. Week 5: $N = 29$, 19. Week 6: $N = 32$, 26. Week 7: $N = 24$, 31. Week 8: $N = 28$, 40. Week 9: $N = 28$, 40. Week 10: $N = 25$, 33. Week 11: $N = 23$, 30.

Figure 10. Mean nectar sugar concentration ($\text{mg}/\mu\text{l}$) in dry v. wet meadow habitats by week. Week 1: $N = 3$, 2. Week 2: $N = 10$, 6. Week 3: $N = 20$, 16. Week 4: $N = 31$, 38. Week 5: $N = 29$, 19. Week 6: $N = 32$, 26. Week 7: $N = 24$, 31. Week 8: $N = 28$, 40. Week 9: $N = 28$, 40. Week 10: $N = 25$, 33. Week 11: $N = 23$, 30.

Figure 11. Mean sugar content (mg) per transect in dry v. wet meadow habitats by week. Week 1:

$N = 3, 2$. Week 2: $N = 10, 6$. Week 3: $N = 20, 16$. Week 4: $N = 31, 38$. Week 5: $N = 29, 19$. Week 6: $N = 32, 26$. Week 7: $N = 24, 31$. Week 8: $N = 28, 40$. Week 9: $N = 28, 40$. Week 10: $N = 25, 33$. Week 11: $N = 23, 30$.

Figure 12. Species' nectar volumes, sugar concentrations, and sugar contents in dry v. wet meadow habitats. Symbols for significance: NS $P > 0.05$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Wilcoxon Rank Sum Test: a. $N = 20, 26$; $W = 61$; $P < 0.001$. b. $N = 20, 17$; $W = 0$; $P < 0.001$. c. $N = 20, 17$; $W = 3$; $P < 0.001$. d. $N = 24, 50$; $W = 807.5$; $P < 0.001$. e. $N = 22, 46$; $W = 241$; $P = 0.007$. f. $N = 22, 46$; $W = 679$; $P < 0.001$. g. $N = 36, 21$; $W = 461.5$; $P = 0.168$. h. $N = 25, 18$; $W = 437.5$; $P < 0.001$. i. $N = 25, 18$; $W = 356$; $P < 0.001$.

Figure 13. Species' nectar volumes, sugar concentrations, and sugar contents in 2018 v. 2019. Symbols for significance: NS $P > 0.05$, # $P < 0.051$, * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$. Wilcoxon Rank Sum Test: a. $N = 22, 33$; $W = 197$; $P = 0.003$. b. $N = 10, 32$; $W = 220.5$; $P = 0.076$. c. $N = 10, 32$; $W = 83$; $P = 0.024$. d. $N = 63, 41$; $W = 997$; $P = 0.0503$. e. $N = 60, 41$; $W = 1712$; $P < 0.001$. f. $N = 60, 41$; $W = 1238.5$; $P = 0.473$. g. $N = 9, 65$; $W = 114.5$; $P = 0.003$. h. $N = 8, 60$; $W = 455$; $P < 0.001$. i. $N = 8, 60$; $W = 148$; $P = 0.082$. j. $N = 21, 11$; $W = 161.5$; $P = 0.125$. k. $N = 16, 8$; $W = 72$; $P = 0.645$. l. $N = 16, 8$; $W = 102$; $P = 0.019$. m. $N = 52, 31$; $W = 1394$; $P < 0.001$. n. $N = 51, 22$; $W = 255$; $P < 0.001$. o. $N = 51, 22$. $W = 899$; $P < 0.001$. p. $N = 16, 34$; $W = 464$; $P < 0.001$. q. $N = 16, 16$; $W = 256$; $P < 0.001$. r. $N = 16, 16$; $W = 216$; $P < 0.001$. s. $N = 33, 38$; $W = 266.5$; $P < 0.001$. t. $N = 30, 30$; $W = 626$; $P = 0.009$. u. $N = 30, 30$; $W = 181$; $P < 0.001$. v. $N = 24, 39$; $W = 108.5$; $P < 0.001$. w. $N = 23, 37$; $W = 851$; $P < 0.001$. x. $N = 23, 37$; $W = 305$; $P = 0.068$.

Supplemental figure 1. Temperatures inside and outside of pollinator exclusion bags. T-test: $N = 38, 38$; $T = -0.58478$; $P = 0.561$.

Figures

Figure 1.



Figure 2.

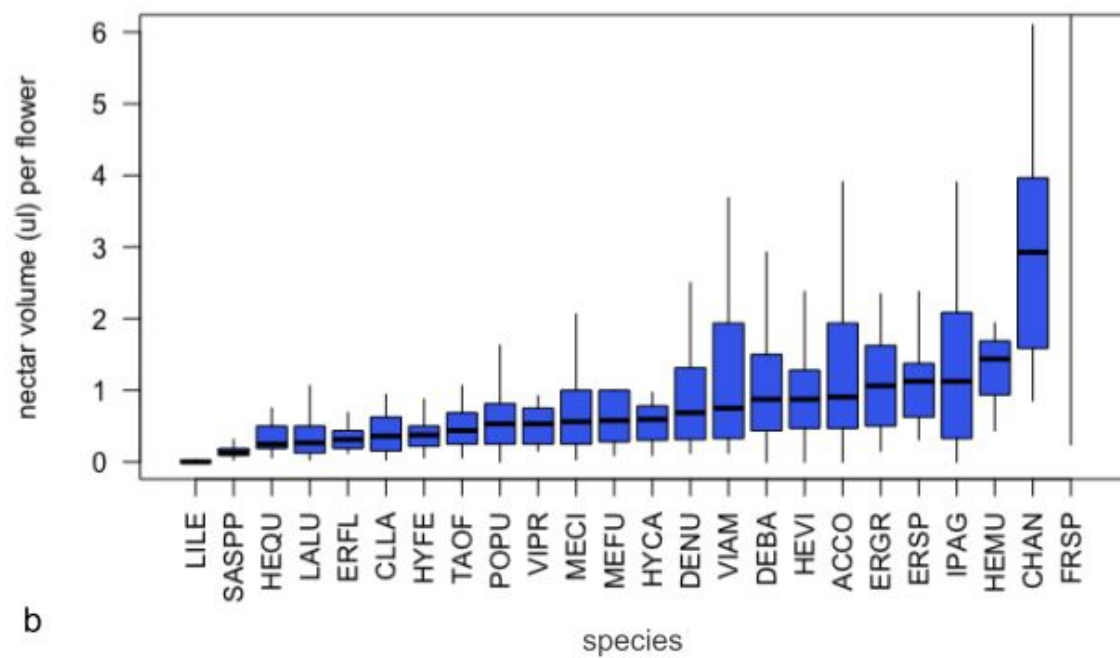
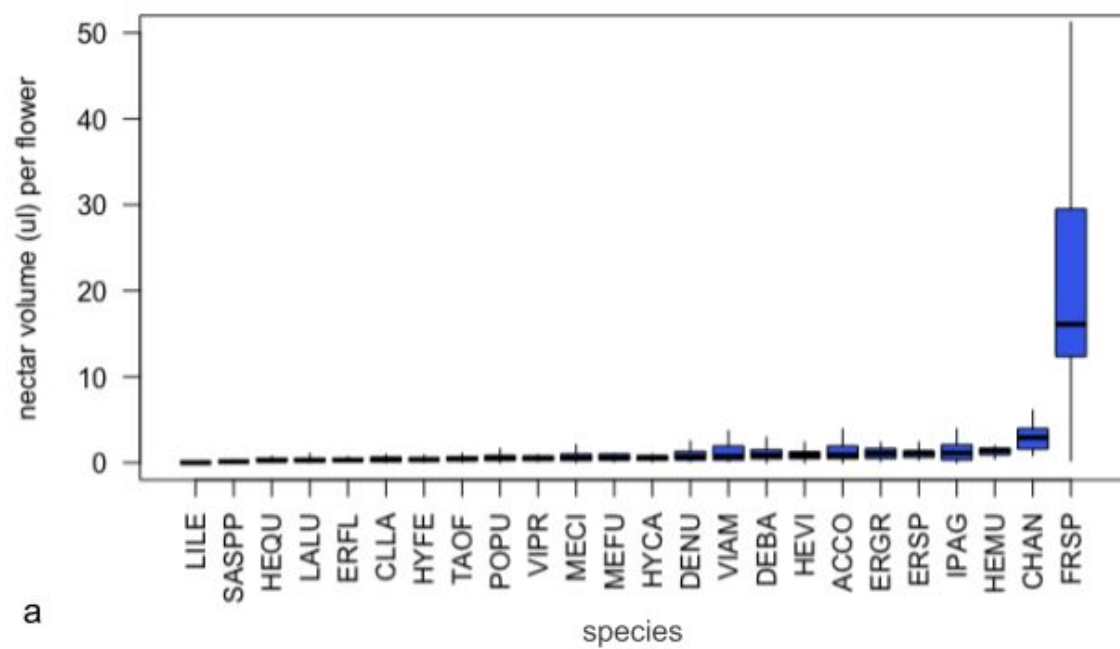


Figure 3.

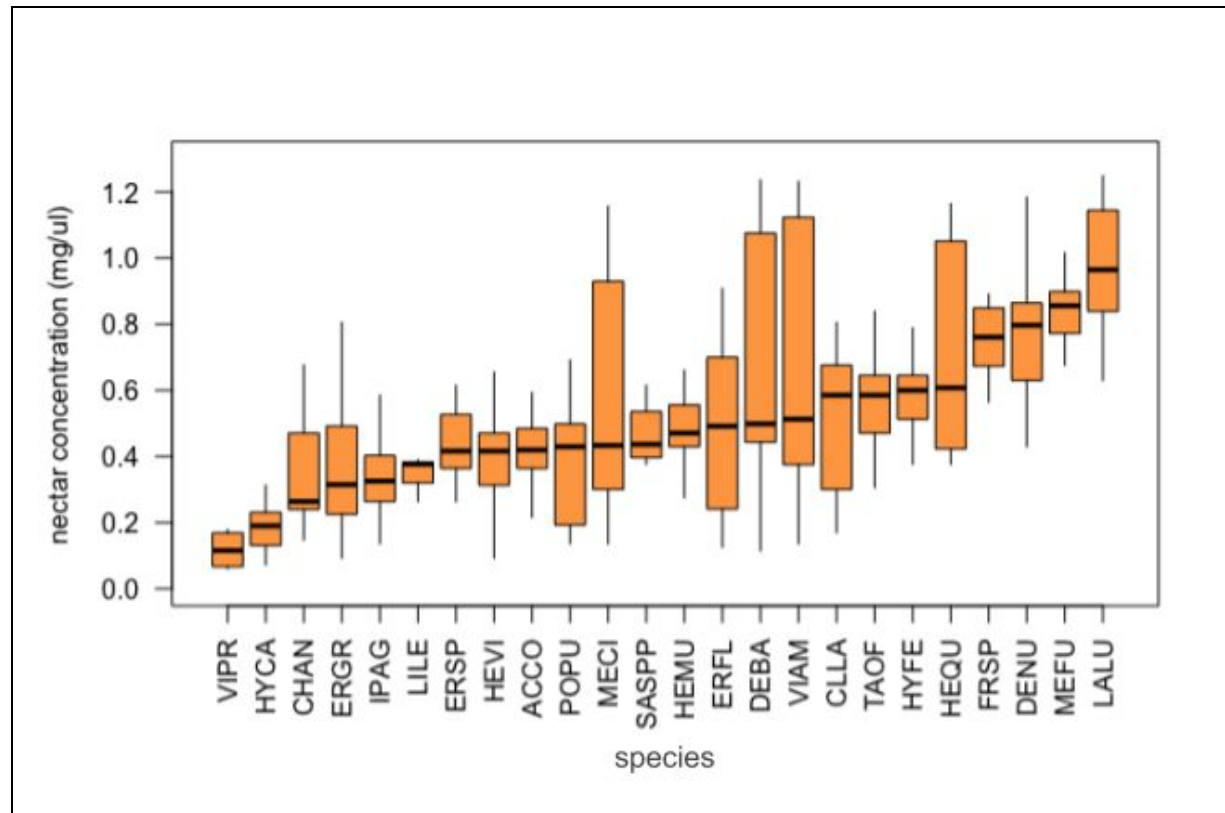


Figure 4.

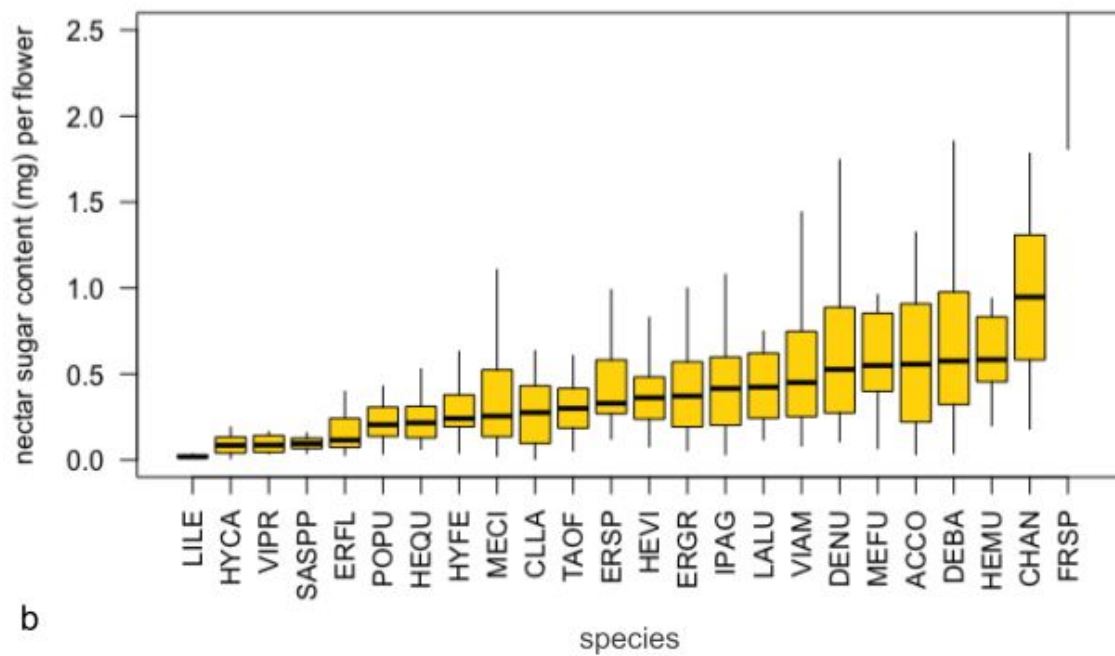
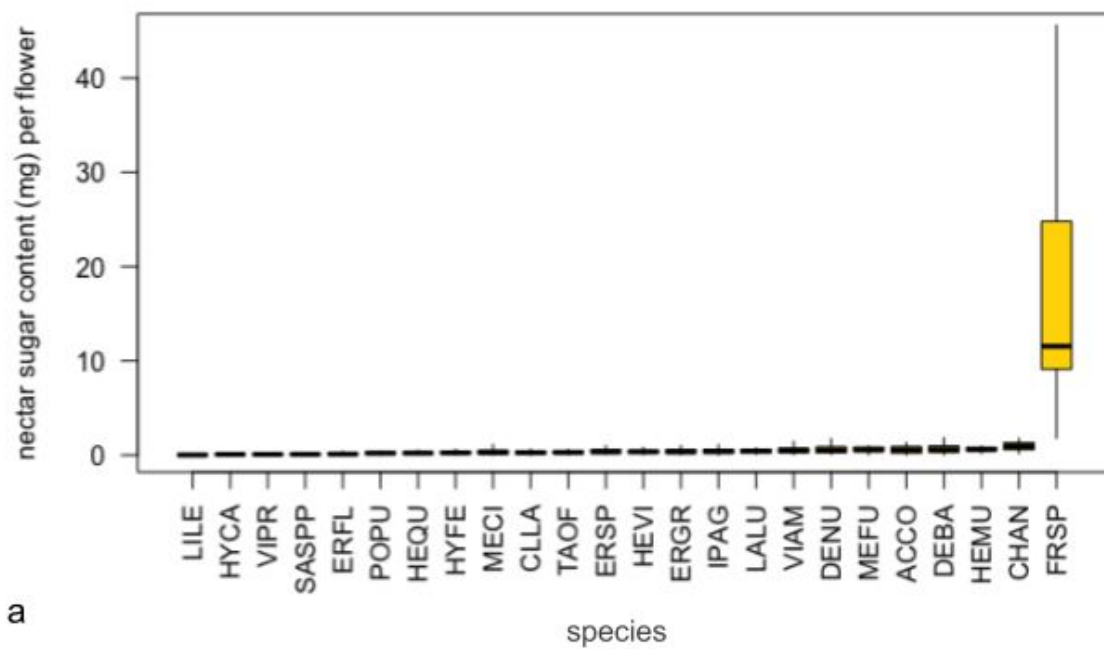


Figure 5.

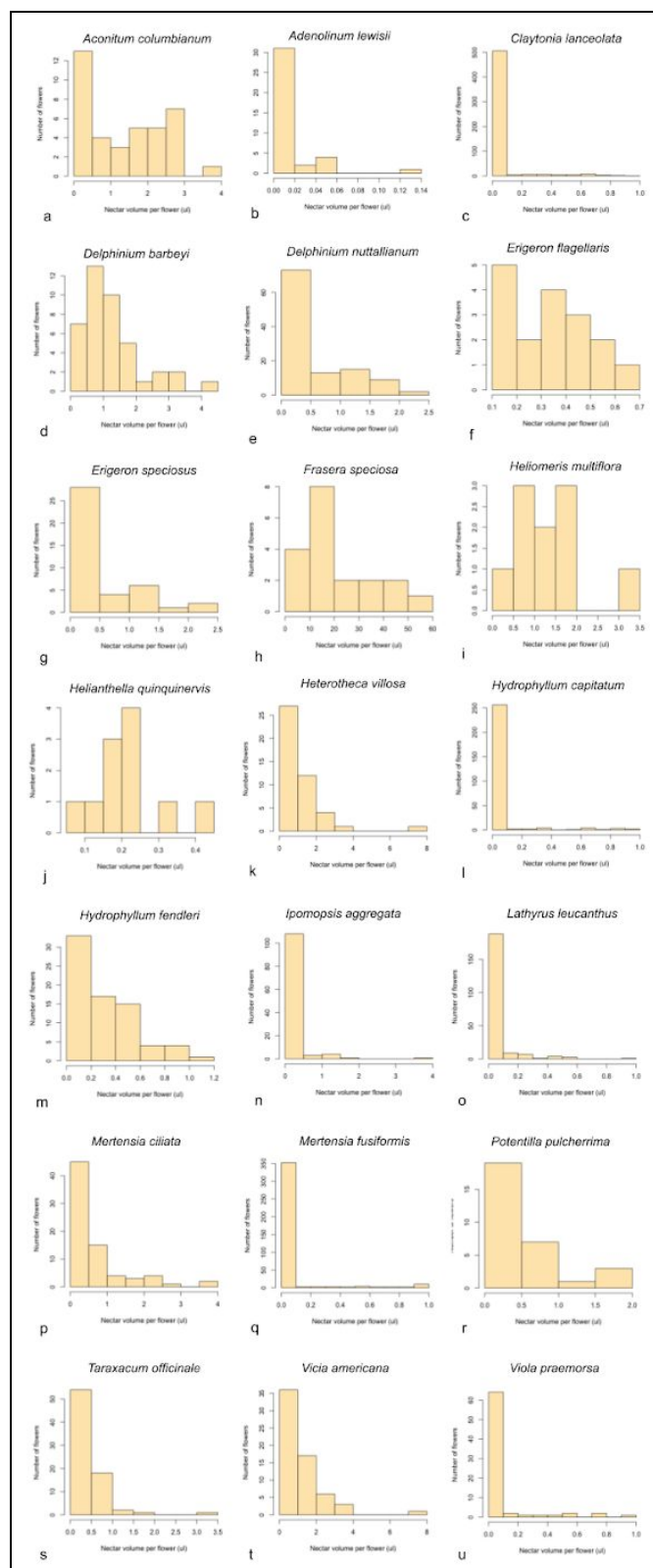


Figure 6.

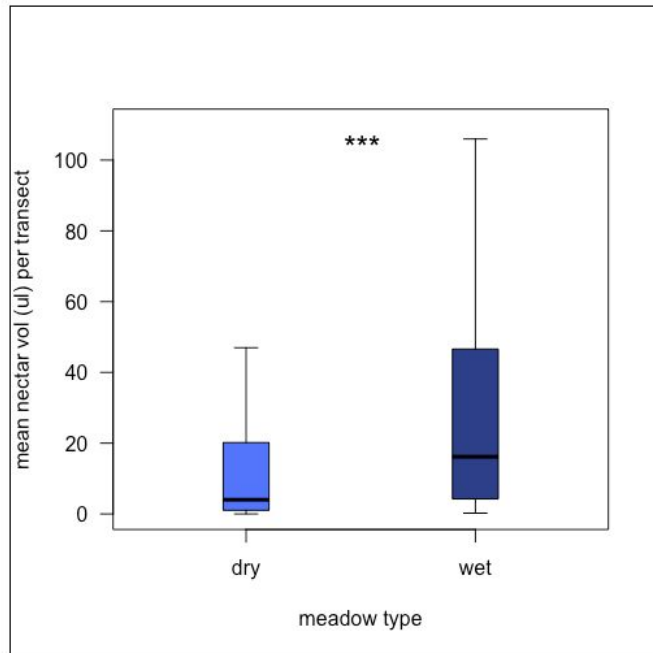


Figure 7.

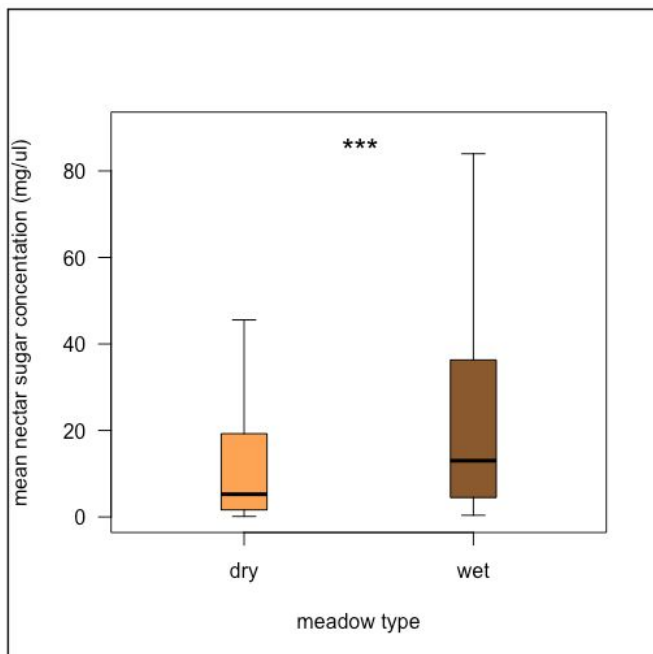


Figure 8.

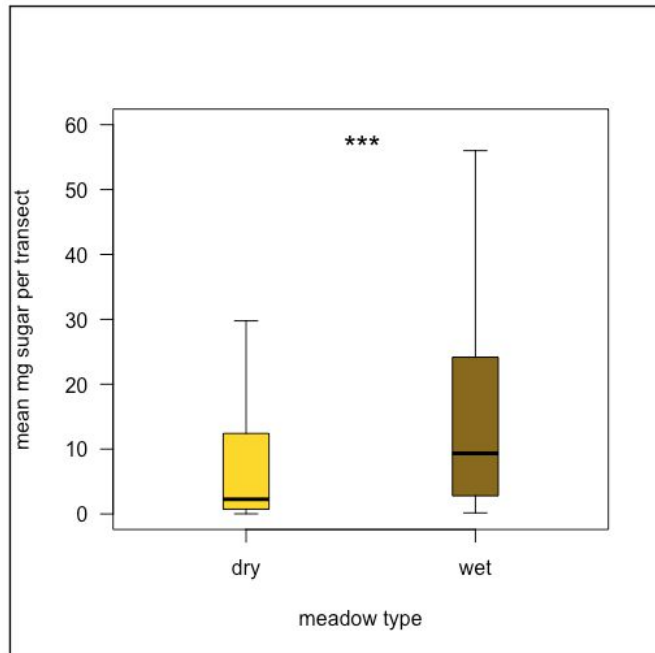


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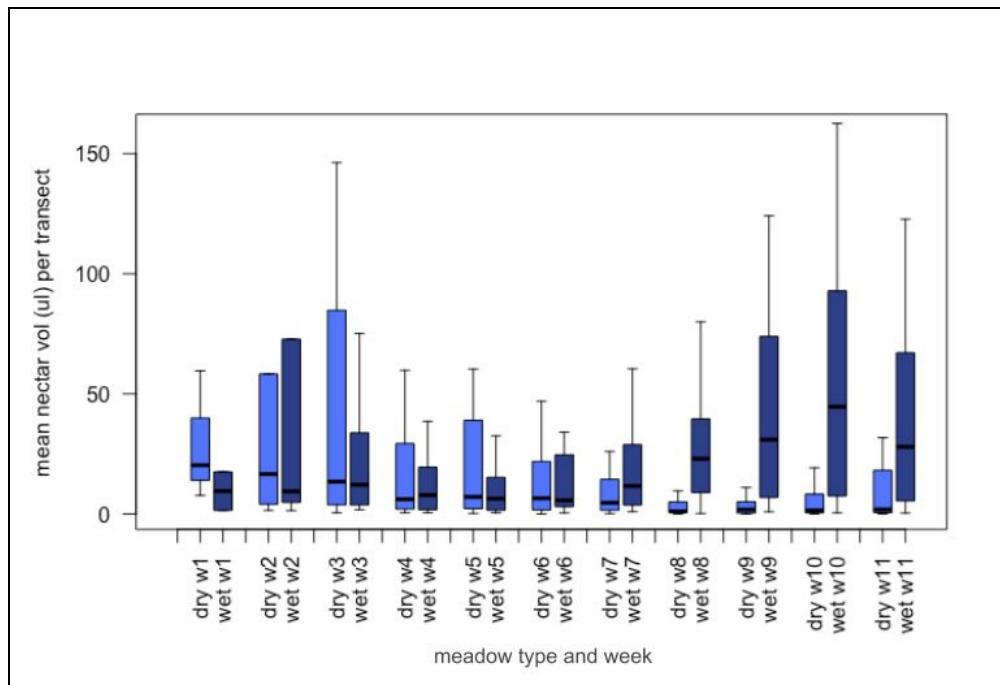


Figure 10.

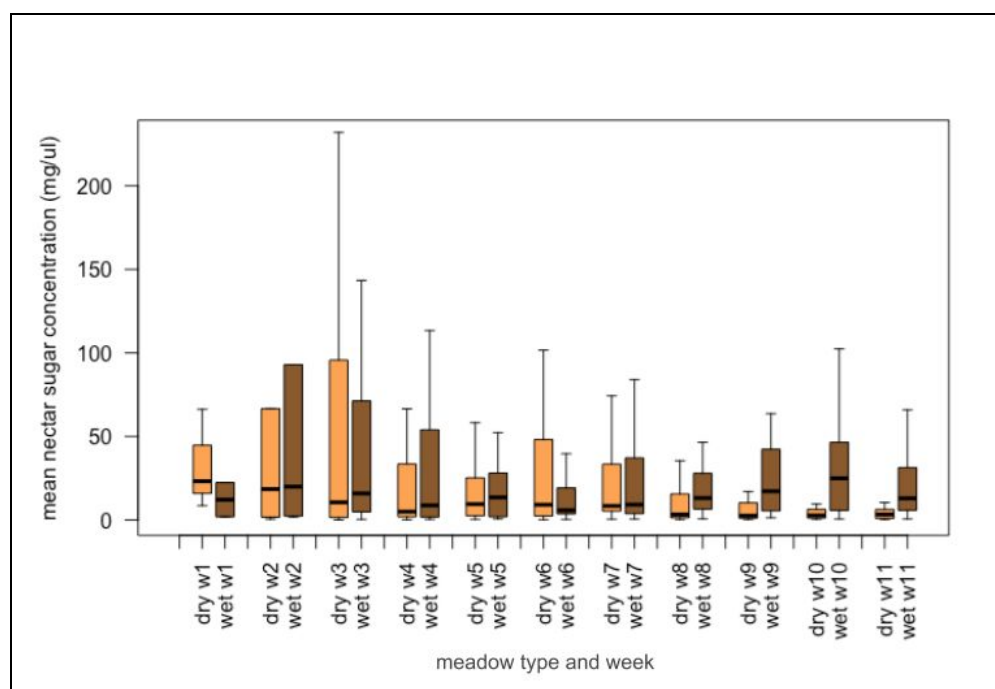


Figure 11.

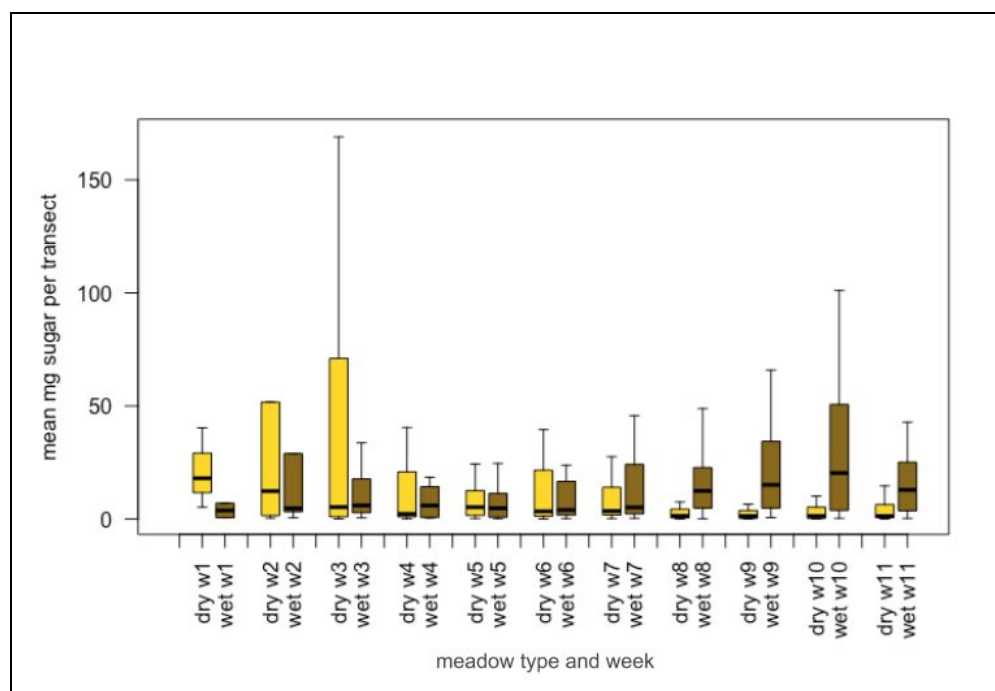


Figure 12.

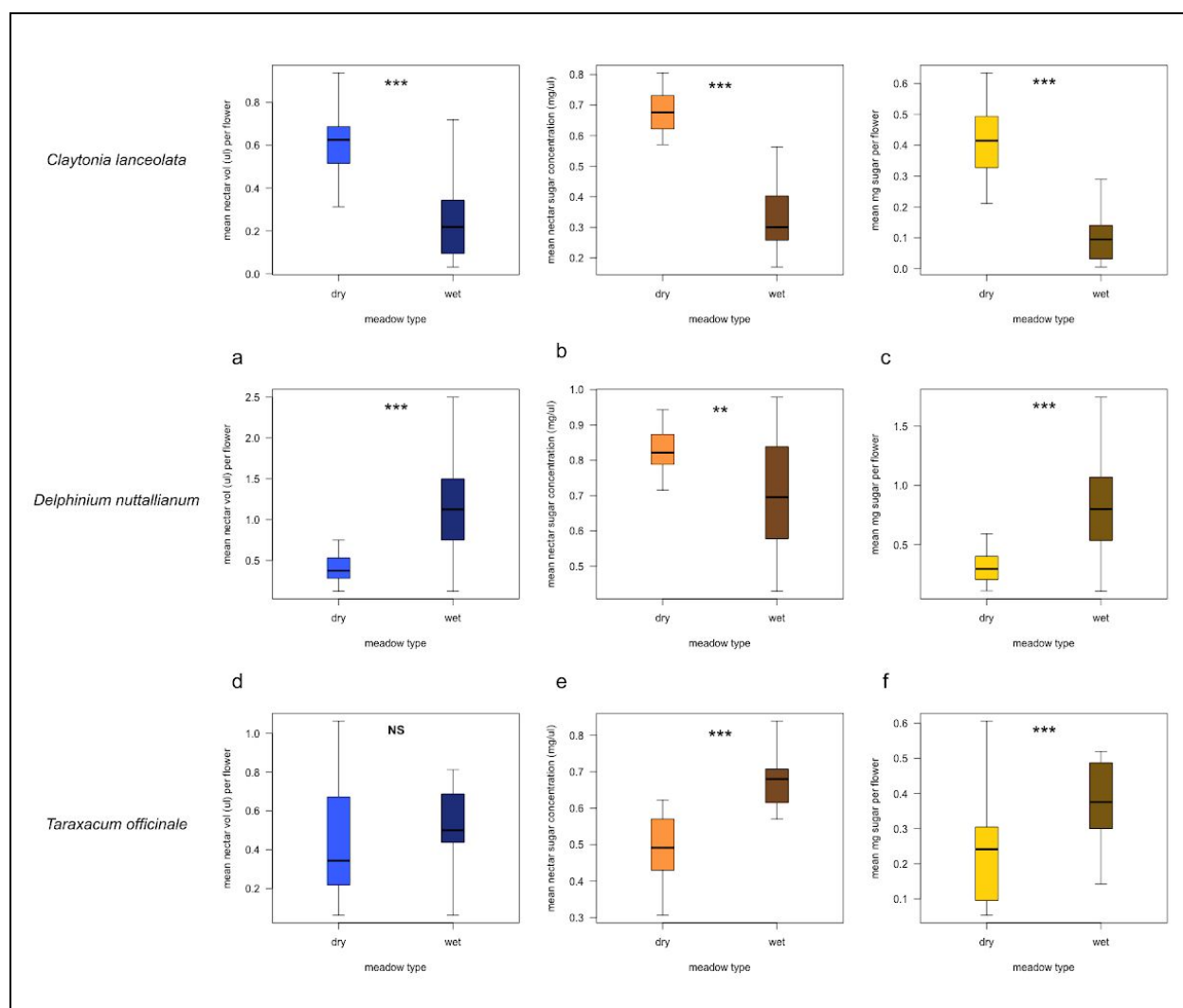
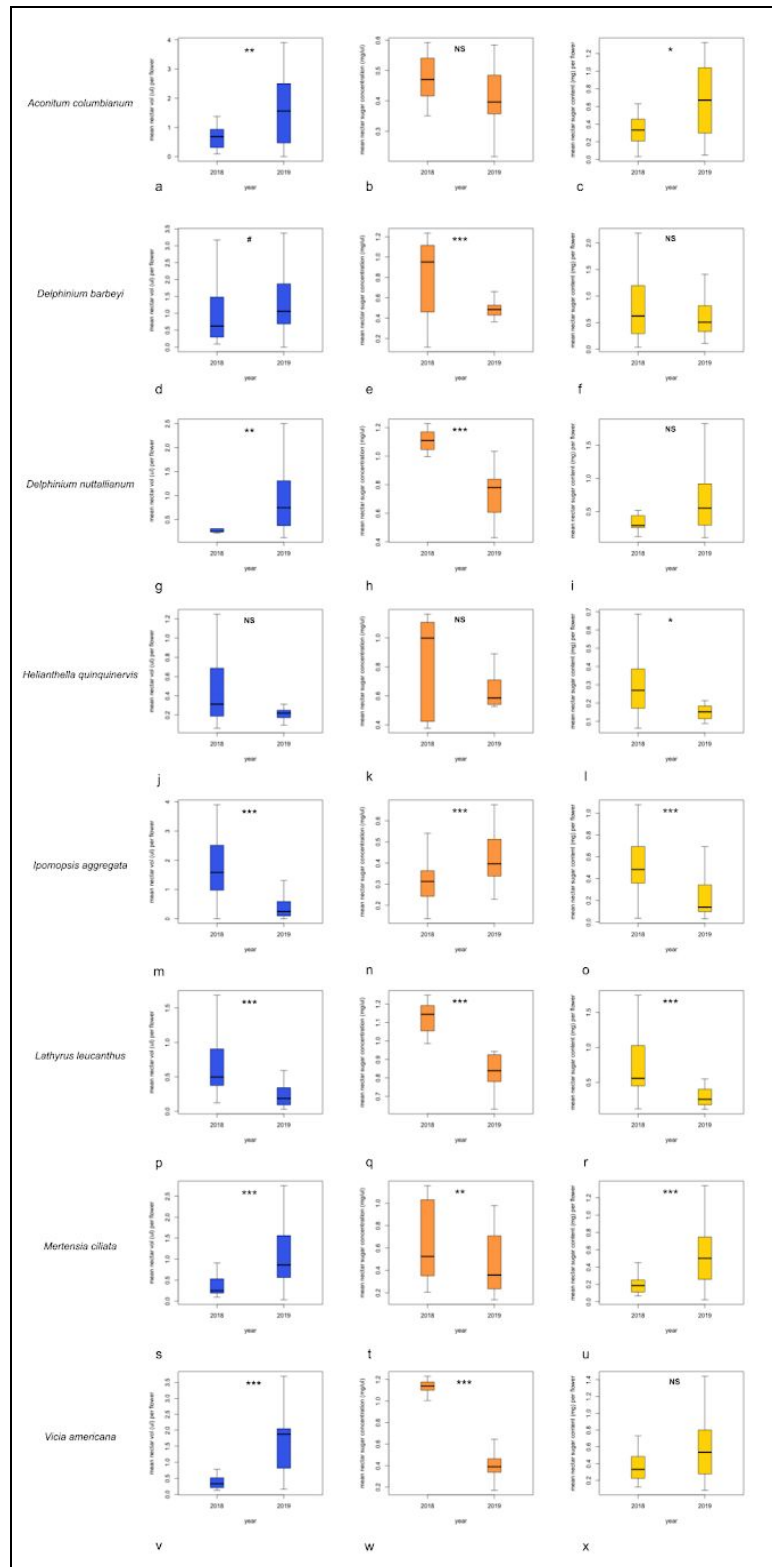


Figure 13



Supplemental figure S1.

