Thomson D.M. Novel data support model linking floral resources, honey beecompetition with bumble beedeclines in coastal scrub

Supporting Information.

Appendix 1. Additional supporting tables.

Appendix 2. Additional supporting figures.

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| Table S1. Variation in precipitation drivers over the period from 1999-2018. | | |
| Year is given as the summer in which bee foraging data were collected. Growing | | |
| years are defined as the period from Sept. 1 to August 31, and days of spring | | |
| rain represents the number of days with precipitation between March 15 and | | |
| May 15. |  |  |
|  |  |  |
| **Year (summer)** | **Total growing year rain (cm)** | **Days of spring rain** |
| 1999 | 37.99 | 22 |
| 2000 | 50.12 | 11 |
| 2002 | 36.09 | 11 |
| 2003 | 36.70 | 27 |
| 2004 | 48.50 | 4 |
| 2005 | 57.48 | 23 |
| 2006 | 61.68 | 28 |
| 2007 | 20.79 | 10 |
| 2008 | 26.88 | 6 |
| 2009 | 29.68 | 6 |
| 2010 | 47.26 | 15 |
| 2011 | 45.35 | 21 |
| 2012 | 32.11 | 15 |
| 2013 | 30.36 | 9 |
| 2014 | 18.54 | 12 |
| 2015 | 32.67 | 8 |
| 2016 | 44.13 | 13 |
| 2017 | 79.62 | 15 |
| 2018 | 27.25 | 15 |
| Mean | 39.70 | 14.26 |
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Table S2. Patches included in the 2015-2018 data collection, listed by approximate spatial location from coastal, southern patches (leftmost) to canyon, northern patches (rightmost). Patch numbers highlighted with dark grey were included in the original model fitting, while those highlighted in pale grey were sampled a mean of 4 times from 1999-2018 but not included in the original model development. Patches with no highlighting were added to the monitoring after 2014. An X indicates the patch was sampled in the corresponding year. Patch 44 data from 2018 were dropped from analyses, because the density of *Phacelia malvifolia* was more than double the next smallest value observed over the entire 1999-2018 monitoring period.

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|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  | **Patch** |  |  |  |  |  |  |  |  |
| **Year** | **BB** | **46** | **34** | **1** | **26** | **5** | **43** | **WP** | **X** | **9** | **40** | **42** | **44** | **27** |
| 2015 |  |  |  | X | X |  | X |  | X | X | X | X | X | X |
| 2016 |  | X | X | X | X | X | X | X | X | X | X |  | X | X |
| 2017 | X | X | X | X | X |  | X | X |  | X | X |  | X |  |
| 2018 | X | X | X |  | X |  | X | X |  | X | X |  | (X) |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
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Table S3. Summary of all models assessed for plant floral abundances, listed by species. The final best fit models are listed first for each species, followed by all other models. The Change column shows the effects added (+), dropped (-) or exchanged (/) and the Δ AIC column the difference in AIC relative to the best fit model.

|  |  |  |  |
| --- | --- | --- | --- |
| **Species** | **Model** | **Change** | **Δ AIC** |
| *Scrophularia californica* | (Scrophularia)0.5~ Spring rain + Phenology + Time + (1|Patch) | Best fit | 0 |
| *S. californica* | (Scrophularia)0.5~ Spring rain + Phenology + Time + Time\*Spring rain+(1|Patch) | + Time\*Spring rain | -1.82 |
| *S. californica* | (Scrophularia)0.5~ Spring rain + Phenology + (1|Patch) | - Time | 7.02 |
| *S. californica* | (Scrophularia)0.5~ Phenology + Time + (1|Patch) | - Spring rain | 5.67 |
| *S. californica* | (Scrophularia)0.5~ Spring rain + Time + (1|Patch) | - Phenology | 1.66 |
| *S. californica* | (Scrophularia)0.5~Growing year rain+ Spring rain + Time + (1|Patch) | Growing year rain/phenology | 3.38 |
| *Stachys bullata* | (Stachys)0.5~Spring rain + Phenology + Time + (1|Patch) | Best fit | 0 |
| *S. bullata* | (Stachys)0.5~ Spring rain + Phenology + Time + Time\*Spring rain+(1|Patch) | + Time\*Spring rain | -1.52 |
| *S. bullata* | (Stachys)0.5~ Spring rain + Phenology + (1|Patch) | - Time | -1.88 |
| *S. bullata* | (Stachys)0.5~ Phenology + Time + (1|Patch) | - Spring rain | 1.32 |
| *S. bullata* | (Stachys)0.5~Spring rain+Time + (1|Patch) | - Phenology | 8.42 |
| *Eriophyllum staechadifolium* | (Eriophyllum)0.5~ Spring rain + Phenology + Time + (1|Patch) | Best fit | 0 |
| *E. staechadifolium* | (Eriophyllum)0.5~ Spring rain + Phenology + Time + Time\*Spring rain + (1|Patch) | + Time\*Spring rain | -1.96 |
| *E. staechadifolium* | (Eriophyllum)0.5~ Spring rain + Phenology + (1|Patch) | - Time | 1.86 |
| *E. staechadifolium* | (Eriophyllum)0.5~ Phenology + Time + (1|Patch) | - Spring rain | 2.72 |
| *E. staechadifolium* | (Eriophyllum)0.5~Spring rain + Time + (1|Patch) | - Phenology | 9.65 |
| *E. staechadifolium* | (Eriophyllum)0.5~Growing year rain + Precipday + Time + (1|Patch) | Growing year rain/ Spring rain | 4.09 |

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| Table S4. Predictors in the *Bombus* abundance model, with estimates for both the original version | | | | |
| (Thomson 2016) and the corrected version used in the current analyses. The structure of the best-fit model (predictors included) was not affected by these corrections. | | | | |
| **Factor** | **Estimate** | **Corrected Estimate** | **SE** | **Corrected SE** |
| (Intercept) | -1.67 | -1.94 | 0.35 | 0.34 |
| *Apis* density previous year | -4.33 | -4.52 | 0.67 | 0.69 |
| *Scrophularia* density | -0.008 | -0.006 | 0.008 | 0.09 |
| *Phacelia* density | 0.14 | 0.13 | 0.04 | 0.04 |
| Phenology (later) | -0.17 | -0.11 | 0.03 | 0.03 |
| *Apis* x *Scrophularia* | 0.22 | 0.22 | 0.07 | 0.08 |
|  |  |  |  |  |

A screenshot of a computer

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Figure S1. Relationship between spring rainfall (number of days) and the density of open flowers/meter of transect for three key forage plants: A) *Scrophularia californica*; B) *Stachys bullata*; and C) *Eriophyllum staechadifolium*. Each symbol represents a transect within a given year. Black circles show the time period originally modeled (2000-2014) and orange triangles the most recent four years of data collection (2015-2018). Days of spring rain quantifies the number of days between March 15 and May 15 with precipitation in each year. Floral densities are shown on a square root transformed scale.

A screenshot of a cell phone

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Figure S2. Relationships between: A) mean *Apis* *mellifera* density/m transect and *Bombus* preference for *Eriophyllum staechadifolium*; and B) *Bombus* preference for *Eriophyllum staechadifolium* and proportional diet (niche) overlap with *A. mellifera*. Each symbol represents an annual value calculated across all observed visits for that year. Black circles show the time period originally modeled (1999-2014) and orange triangles the most recent four years of data (2015-2018). *Bombus* preference was calculated as the proportion of total *Bombus* foragers observed on *E. staechadifolium* divided by the fraction of all flowers that were *E. staechadifolium*; values were square root transformed to remove skew.

A screenshot of a cell phone

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Figure S3. Relationship between mean *Bombus* density/m and proportional diet (niche) overlap with *Apis mellifera* in the previous year. Black circles show the time period originally modeled (1999-2014) and orange triangles the most recent four years of data collection (2015-2018). *Bombus* densities are averages across all transects surveyed in a given year, and measures of niche overlap based on all observed foraging visits for the year. Data for niche overlap in the previous year were missing for the first year (1999), and also in 2003 and 2009 because of gaps in the monitoring time series.

A close up of a map

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Figure S4. Relationships between the independently predicted and observed *Bombus* forager density/m transect in 2000-2014, for three patches not included in the original model fitting. Both predicted and observed values are shown on the same log scale used to develop the original model with data from 1999-2014. The line shows where a 1:1 relationship would fall. Each point represents a single patch within a given year. Individual patches were not sampled in every year (mean = 4 years/patch).

A picture containing bird

Description automatically generated

Figure S5. Relationship between precipitation since Jan. 1 weighted by day in year (Thomson 2016) and the fraction of developing to open *Eriophyllum staechadifolium* inflorescences, from 2009-2014 (black circles) and 2015-2018 (orange triangles). This relationship was used to control for phenological variation between years in the original 1999-2014 model development, but did not predict the 2015-2018 data.