Novel data support model linking floral resources and honey bee competition with bumble bee abundances in coastal scrub

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Many bee populations seem to be declining, threatening essential pollination services. There are many potential causes of bee declines and identifying which matter most for a given species or habitat is critical but challenging. One potentially powerful strategy uses statistical models that link bee abundances with environmental factors, such as floral resource availability or weather. Yet correlations between population trends and environmental variables alone do not confirm causation or mean the same patterns will apply in other times and places.

One way to evaluate whether a model captures key drivers is to test whether that model can predict new and independent data. In this study, I challenged a previously developed statistical model for native bumble bee (*Bombus* spp.) abundances in California coastal scrub with novel data. This model is based on the hypothesis that bumble bees compete with feral non-native honey bees (*Apis mellifera*) for floral resources, especially the most common forage plant, seaside woolly sunflower (*Eriophyllum staechadifolium*). When honey bee abundances go up, bumble bees are excluded from foraging on this key resource and their numbers decline in the following year. Bumble bees also strongly depend on two other plants, *Scrophularia californica* and *Phacelia malvifolia*. In turn, spring rainfall influences flowering; in dry years, both key forage plants and bumble bees are less abundant. These hypotheses were supported by analyses using 15 years of observations from 1999-2014.

In this study, I tested whether data from four new years (2015-2018) showed these same patterns. I also used the statistical model for bumble bee abundances to try and predict from flower and honey bee numbers the number of bumble bees observed in different flower patches (spatially novel), the four new years (temporally novel), or new flower patches in 2015-2018 (both spatially and temporally novel).

The results show that patterns of plant response to rainfall over the four new years of observations followed the hypothesized relationships. Likewise, changes in bumble bee plant use and abundances tracked changes in honey bee competitors as predicted. The statistical model of bumble bee abundances effectively predicted observations in new flower patches and in new years. However, when the data were novel both spatially and temporally the predictions were consistently slightly lower than the actual numbers (biased).

The native California bumble bee *Bombus caliginosus* foraging on *Eriophyllum staechadifolium*.

These findings strengthen support for this model of bumble bee abundances, and the underlying hypotheses that bumble bee decline in coastal California is driven by loss of floral resources due to drought and competition with feral honey bees. Better understanding the drivers of bee decline can help guide strategies to alleviate them. That a simple model can predict changes in bumble bee numbers over time is encouraging and suggests this approach may be valuable for other pollinators.