

Title

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Abstract

1. Understanding the mechanisms driving community stability and whether this stability should be related to the stability of ecosystem functions is important for predicting the resilience of communities to changes in biodiversity. While community stability can be influenced by species richness and asynchrony of species, the relation with the stability of ecosystem functioning provided by this community is less explored, and specially for functions involving several trophic levels such as plant pollination.
2. Using a 5-year dataset across 13 Mediterranean woodland patches, we assessed the effect of the richness and asynchrony of pollinators as drivers of the stability of plant's visitation rate and its relationship between the stability of visitation rate and the stability of the plants reproductive success. In addition, we analyzed whether the year together with richness and visitation rate affected the proportion of fruits and the number of seeds.
3. The stability of plant's visitation rate is mainly affected by the asynchrony of pollinator species abundances while pollinator richness shows contrasting responses depending on the plant species. As for the stability of the plant reproductive success, we found no relationship between the stability of fruits and the stability of the visitation rate, however a negative tendency was observed between stability of seed and the stability of visitation rate. This is because for most years, visitation rates are high enough to prevent pollen limitation, but interestingly, in bad years the effect of pollinator richness on fruit proportion becomes important.

Material and method

Our study was conducted in the southwest of the Iberian Peninsula (Huelva and Seville - Spain). We selected 13 sites in Mediterranean shrub ecosystems that ranged from sites with little to no disturbances to more modified ones with crops and urban areas nearby. These sites had similarity in plant community composition and some of most abundance plant species provide nectar and pollen that attract flower visitors. Each site was surveyed at least 7 times per year during the flowering season from 2015 to 2019 (from March to June). Within each site, we selected 3-4 individuals belonging to 3-9 plant species (mean \pm standard error: 5.92 ± 0.54 plant species per site). All the floral visitors (from now on referred to as pollinators) that contacted with their flowers were registered in visits per flower and minutes by performing timed focal observations to the selected individuals. Only pollinators that could not be identified in the field were captured, stored, and identified to species level in the laboratory. For each plant individual, we counted the total number of flowers and at the end of the season, we recorded the number of fruit and the seeds per fruit. For each site and year, we calculated the visitation rate of pollinators as the number of visits divided by the number of flowers, pollinator richness, the fruit set as the proportion of fruit, and the seed set as number of seed for each plant individual sampled per site.

Stability

For the study of stability, we used 5 plant species (*Cistus crispus*, *Cistus ladanifer*, *Cistus salviifolius*, *Halimium halimifolium*, and *Lavandula pedunculata*) because of they were recorded in at least 5 sites. The

stability of visitation rate was quantified as the inverse of the coefficient of variation (mean/SD) for each plant species in each plot following (Tilman, 1999). To examine the role of richness and synchrony of pollinator species as drivers of stability of visitation rate, we calculate the richness as the total number of pollinator species that visit each plant species in each plot. For synchrony, we used the Loreau and de Mazancourt index (2008), the weighted form of the synchrony index (Gross et al., 2014; Blüthgen et al., 2016), and the log of variance ratio (log VR) (Schluter, 1984; Hallett et al., 2014; Lepš et al., 2018). All of them were positively correlated within each plant species, therefore, data for synchrony assessed by Loreau and de Mazancourt index are presented and included in our further analyses. This synchrony measurement varies from zero, when fluctuations are perfectly asynchronous, to one, when fluctuations are perfectly synchronous. Finally, we express asynchrony as 1-Loreau and de Mazancourt’s index of synchrony. We also calculated the stability of fruit proportion and of the seed number for each plant species in each plot.

Statistical analysis

To evaluate the main drivers of visitation rate stability, we employed linear mixed model to test for relationships between stability and richness and asynchrony including site and plant species as random factor. We used variance inflation factors to check for collinearity between explanatory variables. For a deeper understanding, we also analyzed the respond of the stability for each plant species separately.

For our aim to study whether the stability of the visitation rate influenced in the stability of the plant reproductive success, we run linear mixed models using as response variables the stability of fruit proportion or stability of seed number and as explanatory variable the visitation rate stability. Site and plant species were included as factor random.

To detect whether the effect of pollinator richness and visitation rate is different across the years, we use all plant species sampled. We analyzed the interaction effect richness and year, and visitation rate and year on fruit proportion using binomial generalized linear mixed models, and on the number of seeds employing linear mixed model. The number of seeds per fruit was centered and scaled per plant species to allow meaningful comparisons across species. For all models, we included plant species identity nested within site and site as random effects because of multiple individuals of the same plant species are measured at each site.

Results

Stability of visitation rate and its drives: richness and synchrony

Stability of visitation rate ranged from 0.64 to 9.24 (mean \pm SE: 1.928 ± 0.232), whereas pollinator richness ranged from 2 to 20 (8.128 ± 0.686) and the pollinator asynchrony varied from 0 to 0.998 (0.754 ± 0.032). Our results showed a significant relationship between stability of visitation rate and asynchrony with greater visitation rate stability when pollinator asynchrony increases (Estimate: 4.851; standard error: 1.368) (Fig 1A), whereas the pollinator richness was marginal and negatively related to stability (Estimate: -0.125; standard error: 0.067) (Fig 1B). When we analysed the plant species separately, we observed that all plant species follow the general tendency, except to the *L. pedunculata* that presented a negative tendency between stability of visitation rate and asynchrony, and positive with the richness (Supplementary material-Fig 1).

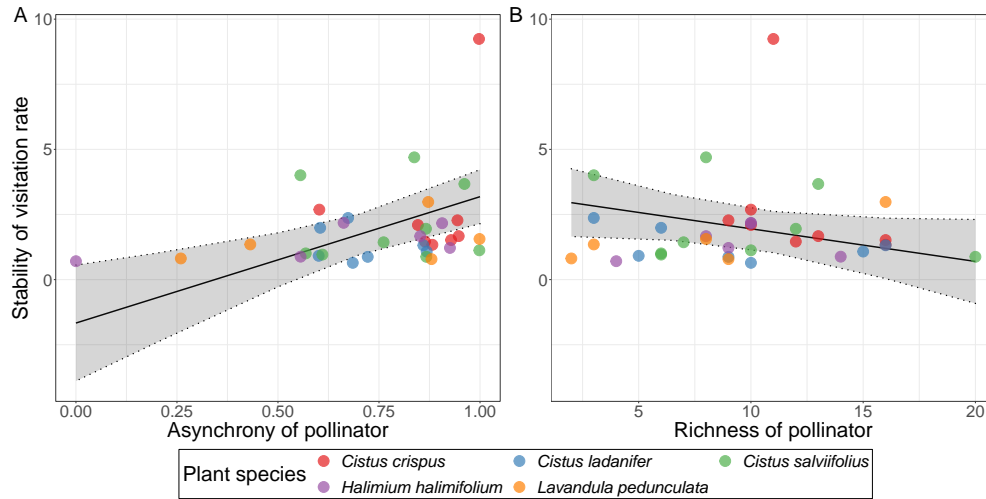


Figure 1. Relationship between stability of visitation rate (calculated as the inverse of the coefficient of variation) and asynchrony of pollinators (Loreau and de Mazancourt's index) (A) and richness of pollinators (B). Dots represent the different plant species included in the analysis.

Stability of visitation rate and stability of the plant reproductive success

Stability of fruit proportion varied from 2.62 to 120.66 (mean \pm SE: 19.806 ± 3.615), whereas the stability of seed number ranged 1.28 to 55.86 (7.018 ± 1.441). When we analyzed whether the stability of the visitation rate affected the stability of the plant reproductive success, we did not find relationship between this and the stability of the fruit proportion (Estimate: -1.547; std. error: 2.611) (Fig 2A), however, the stability of seed number showed negative tendency with the stability of visitation rate (Estimate: -1.887; std. error: 0.959) (Fig 2B).

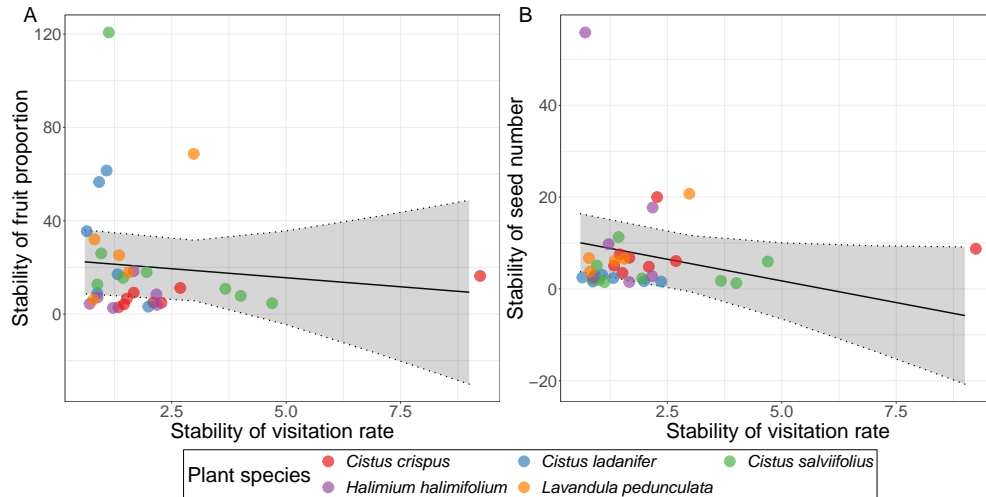


Figure 2. Relationship between stability of plant reproductive success: fruit proportion (A) and seed number (B) and the stability of visitation rate. Dots represent the different plant species included in the analysis.

Effect of pollinators across years on the plant reproductive success

When we analysed whether the effect of pollinator richness and visitation rate is different across the years, we found that both variables showed a significant interaction effect with the year on fruit proportion. Although

we observed a saturation of the fruit proportion, in year like 2017 is showed that a greater richness and visitation rate increased the fruit proportion (Richness - Estimate: 0.395; std. error: 0.15; Visitation rate - Estimate: 25.238; std. error: 5.67). However in 2018, the relationship between richness and fruit proportion was negative (Estimate: -0.147; std. error: 0.05) (Fig 3).

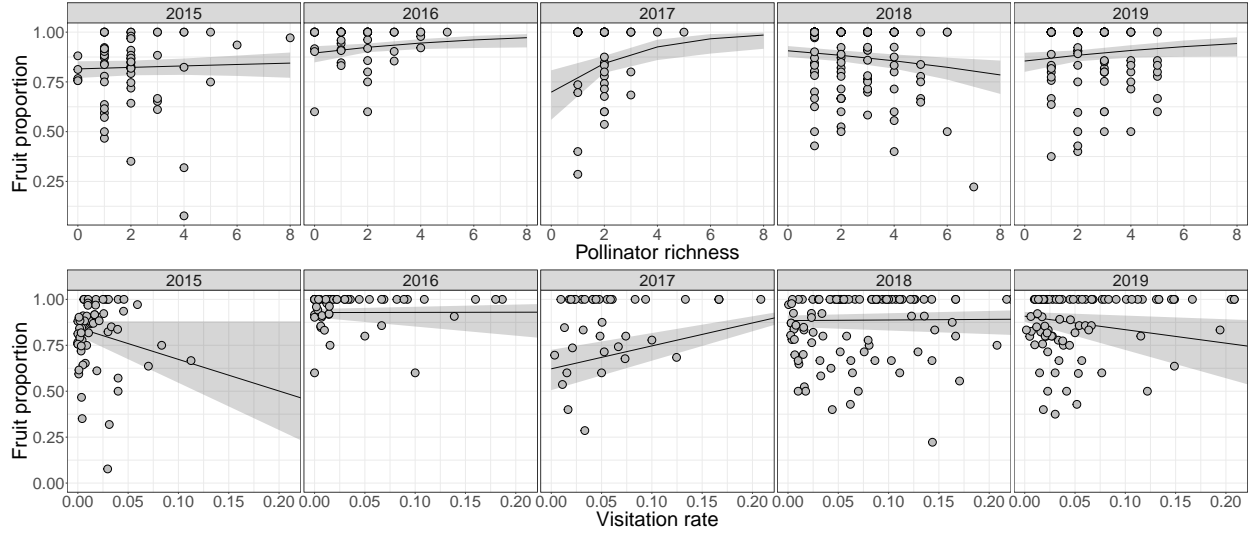


Figure 3. Interaction effect between richness and year (top row), and visitation rate and year (bottom row) on fruit proportion. For the visualization purpose, we omit in the visitation rate (x-axis) the values outside of the 95%.

For the seed number, we not found the interaction effect to pollinator richness, however we found a marginal significant interaction between visitation rate and year. We observed that a higher the visitation rate increased the seed number in 2019 (Fig 4).

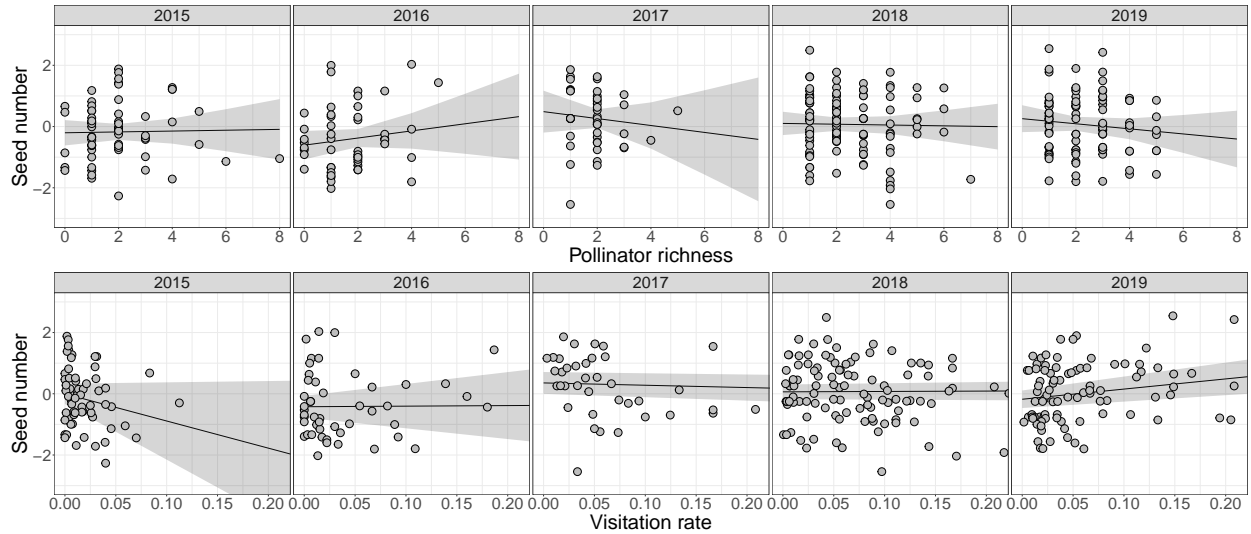


Figure 4. Interaction effect between richness and year (top row), and visitation rate and year (bottom row) on seed number. For the visualization purpose, we omit in the visitation rate (x-axis) the values outside of the 95%.

Supplementary material

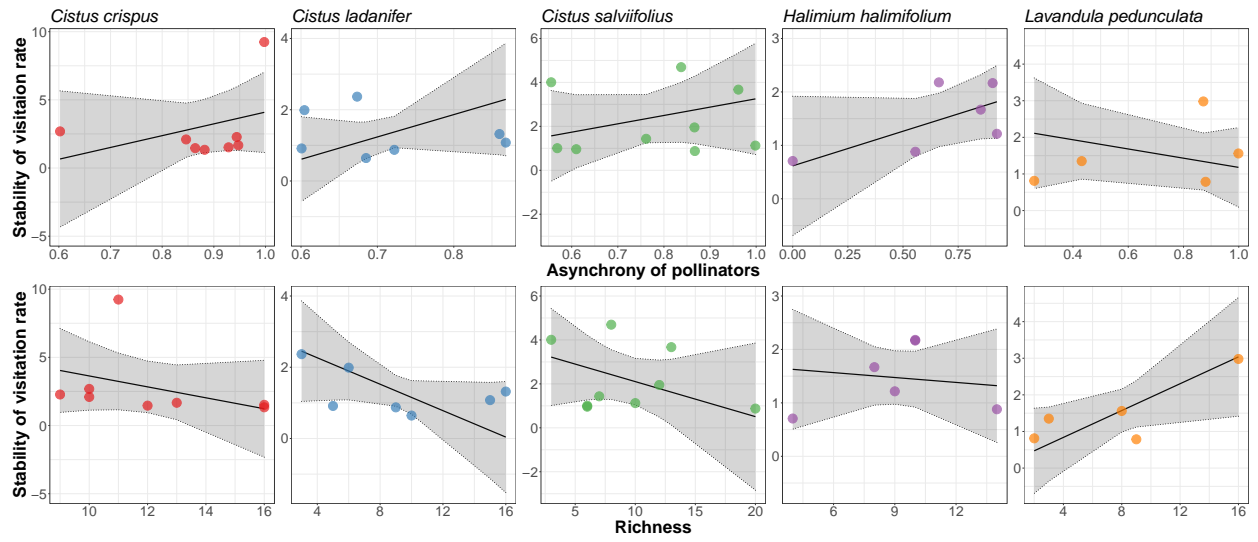


Figure 1. Changes in the stability of visitation rate with the asynchrony (top row) and richness (bottom row) are shown for each plant species