Letters

Can positive frequency dependence facilitate plant coexistence?

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In his opinion piece, Pauw [1] advocated a niche theoretical approach for studying the coexistence of plant species that differ in pollinator use, but are otherwise ecologically equivalent. By treating pollinators as a resource, one can apply the conceptual framework of the Lotka–Volterra model, which shows that coexistence can occur when each species limits its own growth rate more than that of others (i.e., negative frequency dependence). He presented a list of seven predictions, applicable to plant–pollinator communities, that follow from this theory. We endorse the use of Pauw's clearly articulated framework for helping identify the factors responsible for maintaining diverse plant communities. Here, we would like to present one additional hypothesis that we believe could also be useful in identifying how pollinators might promote maintenance of diverse plant communities, namely positive frequency dependence (e.g., intraspecific facilitation). Although Pauw does allude to the possibility that positive frequency dependence occurs in plant–pollinator systems (in the section 'Test 1: intraspecific competition'), we feel that its potential role in maintaining coexistence deserves attention.

Theoretical work has shown that local positive frequency-dependent interactions among conspecifics can promote the coexistence of multiple ecologically equivalent species [2,3]. Critical to these models is the assumption that some feature of the environment that regulates the density of individuals (e.g., habitat quality) is patchy across the landscape (e.g., some locations have poor-quality soil). Intuitively, the mechanism works as follows. With positive frequency dependence, each plant species that first reaches a viable density in some locality should outcompete all other species in that locality. In this way, a spatially structured community, characterized by relatively monomorphic clusters of plants, can emerge from an initially unstructured population. In a homogeneous environment (e.g., one in which species densities are uniform across space), larger populations will then quickly drive smaller populations extinct, leading to the eventual loss of all but one species. However, when the habitat quality varies over space, reduced rates of migration across the regions of low population density can stabilize fluctuations in the relative abundances of species and, consequently, help buffer species against stochastic loss [2,3].

As mentioned by Pauw, positive frequency (or density) dependence can occur in plant–pollinator communities when pollinators spend disproportionately more time in areas with high abundance of the plant species they visit [1,4]. Additionally, positive frequency dependence may occur when plants living in close proximity to heterospecifics are more likely to lose pollen to heterospecific flowers and also to receive potentially harmful heterospecific pollen [5]. This would be especially true for species that rely on largely overlapping sets of pollinators. Pollinators are also known to induce positive frequency-dependent selection by preferring to visit common flowers [6].

To test the ideas we present here, it is first necessary to establish whether intraspecific positive frequency dependence occurs in plant–pollinator systems. This could be done, for example, by growing plants in plots with exclusively conspecifics or plots with conspecifics and heterospecifics and measuring pollination visitation and seed set (e.g., see [7] and also Figure 1b in Pauw's article for an example of density dependence from [8]). Second, one could look for evidence that ecologically similar plant species are distributed in a patchy manner that is consistent with the above-proposed mechanism. In particular, we would expect that the boundaries between species should align with regions of relatively low population density. Third, once the existence of such patches has been established, reciprocal transplants among patches, as well as transplants to border areas between patches, could test whether pollinator visitation is low for the minority species. Although our discussion has focused primarily on positive frequency dependence, it is possible that positive density dependence may have similar effects. Verifying this will, however, require additional theoretical and empirical work.

For the most part, attention has been focused on negative rather than positive frequency dependence when explaining how ecologically similar species might coexist. We think that adding positive frequency dependence to Pauw's well-formulated framework might provide additional insight into the processes maintaining diverse plants and could, therefore, provide exciting avenues for future research.

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Focusing on publication quality would benefit all researchers

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The under-representation of women in academia is a shameful legacy of decades of bias, but is still partly caused by current thinking and actions [1–4]. Cameron *et al.* [5] argue that 'publication quality and impact provide more equitable metrics of research performance and should be stressed above publication quantity.' They support this claim by citing a study published in 2006 of the publication and citation rates of a cohort of 168 ecologists and evolutionary biologists who started to publish between 1990 and 1993 [6]. The study found that female researchers in that cohort tended to publish less than male researchers, but that their average number of citations per publication (a proxy for publication quality) tended to be higher than for male researchers, given a certain publication level (the number of citations per publication was found to be positively correlated with the number of publications) [6]. Do current data still show that stressing publication quality or impact rather than quantity would benefit the chances of female ecologists?

Data retrieved in November 2012 from approximately 1600 Google Scholar profiles (those of researchers who selected the research interest 'ecology' for their profile) showed a strong (r^2 ≈80%) positive correlation between the total number of citations and the total number of publications, for both female and male researchers, with no significant differences in either intercept or slope (Figure 1A). The average number of citations per publication also increased with increasing number of publications, for both female and male researchers, with no significant differences in either intercept or slope (Figure 1B).

An ANCOVA confirmed the lack of significant differences for female versus male researchers in the correlation between the total number of citations and the number of publications {$n = 1616$, $R^2 = 0.80$, log total citations = 0.198 [standard error (s.e.) 0.031] + 1.543 (s.e. 0.019) log publications ($P < 0.001$), gender ($P = 0.09$)} and between the average number of citations per publication and the number of publications [$n = 1616$, $R^2 = 0.35$, log total citations = 0.349 (s.e. 0.026) + 0.485 (s.e. 0.016) log publications ($P < 0.001$), gender ($P = 0.17$)].

Both for female and for male ecologists, the total number of publications is a weak predictor of the average number of citations per publications, because there are many confounding factors [e.g., age, career interruptions, child and elder care duties, country, degree of self-citation, English as mother tongue, independent fellowships, institutional affiliation, interdisciplinary projects, (international) collaborations, (invited) lectures, mentor support, number of review papers, supervised students and postdocs, use of social media, teaching and peer review load, tenure status, etc.], but the main point is that, on the whole, gender does not affect the correlation.

Given that gender is a not significant factor in these correlations, publications by female ecologists now appear to have the same citation impact as those by male researchers. Given the lack of sustainability in current growth rates of scientific publications [7], it makes sense to promote publication quality rather quantity [8], but this will bring benefits to all researchers, not only to female ecologists.

The scientometric data relating to ecologists indexed in Google Scholar also provide clear evidence of the lack of online visibility of female ecologists, who are only represented by approximately 20% of the profiles. This lack of online representation could be a factor contributing to the leaky pipeline [9], although causation is also likely to run from the leaky pipeline to low online visibility. The data confirmed that there is still a leaky pipeline in ecology, because the proportion of female ecologists with a Google Scholar profile declined with increasing number of publications, total citations, h index, years since first citation, and h index divided by years since first citation (Figure 2A–E). Female ecologists are instead

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