Hovering among flowers: understanding patterns of biodiversity through plant–hummingbird interactions

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A remarkable three-country project is examining the ecological interactions between plants and hummingbirds, and what this means for conserving ecosystems. This article presents some fascinating findings.

No other bird can compare to a hummingbird. **1** Saw-billed Hermit *Ramphodon naevius*, Morretes, Paraná, Brazil, February 2019 (Sergio Gregorio).

pollination service these birds provide (Potts *et al.* 2010).

In southern Costa Rica there are several hummingbird species that only occur in that region and northwestern Panama, such as Talamanca Hummingbird *Eugenes spectabilis* and White-tailed Emerald *Microchera chionura*. Because of their very local distribution, populations of these species are inherently sensitive to decline and might face conservation difficulties in the near future. In Brazil, Hook-billed Hermit *Glaucis dohrnii* is a Vulnerable endemic of the central Atlantic Forest. In Ecuador, five hummingbird species are globally threatened endemics, including the recently discovered Blue-throated Hillstar *Oreotrochilus cyanolaemus* (Critically Endangered, with a population estimated to be between 250–750 individuals: see Freile 2019 and the cover of the present issue). In this discouraging scenario it is essential that scientists do their best to generate first-hand knowledge that can be used in conservation action. For example, we can identify critical food plants that hummingbirds require to guide resource managers in habitat-enrichment and -restoration processes.

The EPHI project: an overview

With this aim in mind, in 2017 we initiated research into the ecology of plant–hummingbird interactions (abbreviated to EPHI: see hummingbird.bio) in Costa Rica, Ecuador and Brazil. The project is led by the Swiss Federal Research Institute (WSL) in collaboration with the Universidad Estatal a Distancia, Aves y Conservación and Universidade Federal do Paraná, among other organizations.

Inspired by the extraordinary diversity of hummingbirds and their food plants in the three countries, we are documenting the temporal and spatial variation of plant–hummingbird interactions. We use this information to build interaction networks showing which hummingbirds use which plant species (Fig. 21). From these networks we can gain a deeper understanding of hummingbird communities, and identify which flower resources are key in a hummingbird's diet or which hummingbirds are specialized, foraging on flowers of only a handful of plant species available.

Determining the level of species specialization in ecological communities is important for conservation efforts and for advancing our scientific understanding of how so many similar species can live in one place. There is a classic long-standing hypothesis in ecology that resource specialization is important for maintaining high species diversity. The idea is that if all species living in the same place use exactly the same resources, then one species would be a slightly better competitor and over time would outcompete other species. As a result, diversity would be lower and only the best competitors would persist. However, if hummingbirds are specialized and use different resources, competition is lower and more species can persist in the same place because each species uses different resources (Tilman 1982, MacArthur 1984).

Specialization is also important from a conservation perspective. This information is very relevant for restoration initiatives because the right mix of flowers will provide resources to both generalist hummingbirds, which forage on a broad array of flowers, and specialist hummingbirds, which require specific plant species. If certain species are highly specialized and use only a few flower resources, then it is essential to make sure that these resources are protected. The same is valid from the plant perspective: if it is pollinated by only a few species of hummingbird, it is crucial to safeguard these hummingbirds as well. Given the importance of specialization in ecology and conservation, we evaluate here how it differs among our three biodiverse regions.

How do scientists measure specialisation?

To find out which hummingbirds use which flowers we first needed to create pollination networks like the one depicted in Fig. 21. This required 22 people actively collecting data from 32 sites across the three countries! Establishing transects along an elevation gradient from about sea level to 3,500 m, we recorded hummingbirds visiting plants, flower abundance and species morphology – and did so for more than two years to account for temporal variation.

We used time-lapse cameras combined with MotionMeerkat software (benweinstein.weebly.com/motionmeerkat.html) to catch hummingbirds 'red-handed' at the moment they visit the flowers. This approach enabled us to obtain valuable data through thousands of pictures and thus identify which plant species are the most and least favourite repast of hummingbirds.

We also photographed hummingbird-visited flowers and hummingbird bills to later use sophisticated computer measurement tools to collect morphological data. These data allowed us