EDITORIAL

SPECIAL ISSUE ON ECOLOGY AND EVOLUTION OF INTERACTIONS

Interactions connect everything, everywhere, all the time. Interactions among organisms and with their environment play a central role in species evolution and are fundamental in Ecology. Interactions influence the organism life cycle with profound effects on establishment, growth, reproduction and dispersal. Thus, organisms are not isolated entities and that their interactions with other organisms and the environment can explain almost all of their structural and functional traits as well as where they live. Ecologists and evolutionists should make an effort to work together and fill gaps in our understanding about the *continuum* from the species evolutionary history to their current context in order to project their future. For this special issue, we invited researchers to contribute with reviews and original studies that deal with the multiple dimensions of the ecology and evolution of interactions, emphasizing pollination and herbivory, from population to community and landscape levels. We aimed to assemble studies that contribute with original data contextualized on the theoretical background and that also presented the scenario for some contemporary topics on the ecology and evolution of interactions, especially stimulating an integrative approach amongst different types of interactions. With this special issue, we expect to stimulate and challenge researchers to consider their questions in broader ecological and evolutionary contexts, considering the *continuum* in which interactions can happen in nature.

In the first article of this special issue, *The potential of plants to mediate the interaction between herbivory and pollination*, Rezende and Pareja reviewed plant traits that are affected by herbivory and mediate the interaction with floral visitors and potential pollinators, with consequences to fruit and seed production. They synthesized that the effect of herbivores on floral visitation tends to be neutral or negative, but does not always lead to negative impacts on seed production. The authors also highlighted that future studies should explore finer mechanisms by which herbivory affects pollination, highlighting natural history, pollination effectiveness and the role of the chemical background that flowers are presented to pollinators. This later topic is explored in the second article of this special issue.

Volatile organic compounds as secondary products of plant metabolism play an important role for several functions associated with mutualism such as pollination, but also to antagonistic interactions processes such as herbivory or dishonest signaling. In the second article of this special issue, *The role of floral volatile organic compounds in plant-insect interactions*, Baldelomar and co-workers reviewed this topic and showed that volatile organic compounds could act synergistically with visual signals, ensuring the attention of pollinators for long periods of time and/or long distances. Although the importance of the volatiles for animal-

plant interactions is recognized in the literature, few studies have studied the evolution of scent as a floral trait, which is still an open field for original researches.

The way by which animals perceives plants as resources depends on their cognitive abilities to obtain, retain, and subsequently use the sensory information during decision-making processes in different contexts. In the third article of this special issue, *How bees perceive flowers and why it is important*, Melo and co-workers showed that the attraction of floral visitors is directly related to a great diversity of visuals and olfactory signals, as well as secondary metabolites. Moreover, the variation in the resource content can affect floral visitor response and, consequently, plant reproductive success. Such perspective in plant-pollinator interactions is often neglected in the traditional literature. In this review, the authors compiled a series of relevant and recent examples of the main signals emitted by flowers and perceived by bees, either by a single sensory modality or through multiple modalities. Plant signalling and animal perception are the first step to understand the evolutionary ecology of mutualistic and antagonistic interactions among species.

How do plants make floral resources available to animals and how does this interfere in degree of the interaction dependency? This question is explored by Barônio and co-workers in the fourth article of this special issue titled *Between flowers and visitors: strategies of availability and collection of floral resources*. The authors highlighted that morphological and behavioral differences among visitors discriminate them as pollinators or thieves/robbers, which implies distinct consequences for plant fitness. Then, the authors discussed plant strategies to maintain pollinators visiting flowers without wasting floral resources, as well as the strategies used by floral visitors to optimize their foraging as a function of the resources. Although plant-floral visitor interactions tend to be mutualistic, there is some mutual exploration between these organisms with benefits and costs for both. Such contemporary view that mutualism are not completely beneficial has allowed advances in the view of exploitative mutualisms as a rich scenario for empirical research in the tropics.

Plants can also establish a mutualism with insects in a protective relationship, as the classic example of ant-plant interactions mediated by extrafloral nectaries (EFNs). In *Protection mutualism: an overview of ant-plant interactions mediated by extrafloral nectaries*, Calixto and co-workers reviewed original scientific papers addressing the topic “protection mutualism in ant-plant interactions mediated by EFNs”. The authors showed that recent studies are improving the knowledge on protection mutualisms considering ant-plant ecological networks and how they can shape communities, going beyond the simple description of the indirect benefits of the presence of ants on plants, as has been traditionally done. In this fifth article of this special issue, the authors also discussed the current EFNs evolutionary hypotheses, the existence of conditionality in ant-plant protection mutualism, providing some perspectives to inspire new studies in this area.

Interactions between organisms are often classified in terms of positive or negative relationships. However, the current understand is that interactions could vary from mutualistic to antagonistic on a *continuum*. A classic example of an interaction that could be classified as mutualistic and antagonistic at the same time is the extremely specialized interaction between figs and fig-wasps. Such in-between interactions are more prone to be exploited by a third part, as the case of the galling *Idarnes* reported by Silva and Pereira in the sixth article of this special issue. In *How to be a good non-pollinating fig wasp: galling wasps* (Idarnes *group* flavicollis) *do not interfere with the floral receptive*, the authors experimentally described the lack of effect of the non-cooperative galling wasp in stigma receptivity and fig attractiveness. However, during infestation events, the non-pollinating fig wasps can reduce the time window during which pollinators can enter the figs, potentially affecting pollination and the plant reproductive outcome.

To interactions occur, the partners should have their life cycles well synchronized. In the seventh article, Pfeffer and co-workers described the morphological and phenological relationship of the *Matayba guianensis* and the galling insect *Bystracoccus mataybae*. In *Building two houses on a single host plant: galling insect synchronizes its life cycle with plant phenology*, the authors highlighted the specific phenological synchrony between these galling insects and their host plants that maintains the univoltine cycle of the system in the climatic seasonal Brazilian savannah.

Climatic seasonal variation can also affect the interaction between pollinivorous and plants, ultimately influencing the indirect effect between interactors that share a common floral resource. Such effect should be even greater between generalist bees, which occur in the same place and time. In *Trophic niche and floral resources partition between two species of* Melipona *(Hymenoptera, Apidae) in the eastern Amazon*, Gostinski and co-workers reported the pollen spectrum of bee corbiculae pollen load throughout the year and described the pollen niche overlap between two stingless bee species. Their data emphasize the importance of such generalist native bees for the maintenance of both native and cultivated plant species along all the year. Moreover, the potential resource sharing, which could have an immediate impact in the local *Melipona* honey production in the Amazon region, is also discussed.

In higher levels of biological organization, interactions among organisms from different species may affect the structure of communities, which are often presented as networks and their metrics. There are different ways to infer such networks, being the cues of visitation (pollination networks) and pollen load (feeding networks) the most common methods to infer plant-pollinator networks. In *Floral visitation network versus pollen-transport network between bees and flowers in the Atlantic Forest in South Brazil*, Ribeiro and co-workers used both methods to infer the interaction patterns of a bee-plant network and to present how they can bias network metrics such as the degree, the specialization index, and the strength of the species.

Interactions among species also reflect ecological processes that structure communities. Interspecific competition, for instance, is traditionally considered one of the main ecological processes that control species coexistence. In the tenth article of this special issue, *Interspecific competition is not an important structuring process in a tropical tree community*, Ribeiro and co-workers, empirically tested whether competition among tree species is really an important ecological process in a submontane plant community in the Brazilian Atlantic forest. The study highlighted that other processes, such as intraspecific competition, diffuse competition and neutrality are also important in structuring this community.

In the last article of this special issue, species interactions are explored at the landscape scale by Moreira and co-workers. The literature suggests that the effect of agriculture on biodiversity and ecosystem services is context-dependent. In *Beyond good and evil: context-dependent effects of agriculture on pollinators' communities and its interactions*, the authors assessed the effect of agriculture and landscape heterogeneity on the maintenance of pollinator diversity and ecosystem service of pollination in agro-natural landscapes in Chapada Diamantina, Brazil. The authors used plant-pollinator network approach to compare two landscape groups, one with low proportion of agriculture and high landscape diversity and the second with high proportion of agriculture and low landscape diversity. The network metric (number of links) and the pollinator diversity responded to the proportion of agriculture in the landscape and also landscape heterogeneity. In sum, even if agricultural areas can favor some pollinators, there are evident losses of pollinator diversity and plant-pollinator interactions associated with the landscape homogenization.

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