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Editorial overview: Ecology: Beyond a taxonomically driven approach for describing pattern and process in complex insect communities

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Insect community ecology has traditionally encompassed measures of taxonomic diversity (e.g., alpha, beta) and their biogeographical correlates such as latitude and connectivity [1,2]. Or, research has focused on quantifying food webs based on taxonomic diversity, resource breadth and trophic interactions [3,4]. For this section on community ecology we solicited contributions from researchers working in different types of communities (agricultural, aquatic, tropical, invasive, detrital) who are pushing the boundaries beyond traditional taxon-specific approaches toward a more functional perspective. Each paper makes the point that insect communities would be better understood if they were described and/or quantified using measures unrelated to taxonomy. Some authors converge on similar metrics, whereas others advocate entirely distinct methodologies. Here, we briefly highlight the core arguments laid out by each set of authors, and attempt to synthesize the causal factors driving both the convergence and divergence in approaches across papers.

In the first review, Micky Eubanks and Deborah L Finke consider what measures of communities should be used to better understand and potentially manipulate insects in agroecosystems. Given that maximizing crop production is an ultimate goal in these managed systems, it is not surprising that this topic takes on a process-oriented perspective to pave the way toward future application in plant protection. Studies of insects in agroecosystems tend to focus on direct trophic interactions such as herbivory, and predation or parasitism of herbivores. Indeed, tracking food web linkages has a long history in crop environments for informing biocontrol efforts [5]. Eubanks and Finke emphasize that merely identifying trophic links among taxa may be insufficient to accurately predict the outcome of species interactions. Instead, they advocate the study of a network of indirect effects, or 'interaction webs', including apparent competition, non-consumptive predator effects on prey behavior and/or physiology, and mutualisms (e.g., ant-plant/Hemiptera). Each of these three interaction types fall outside of the bounds considered by traditional food web ecology, but have been addressed to some extent in natural communities [6,7]. The authors astutely demonstrate how their inclusion is necessary for future studies in agriculture, despite generating counterintuitive expectations that shatter widely held perceptions, for example, that herbivores may sometimes *increase* plant fitness.

Jani Heino and Barbara L Peckarsky continue along the same line in the second review, demonstrating that a traditional food web approach is also insufficient for understanding stream insect community structure.

However, rather than focus on indirect effects, as Eubanks and Finke did, they suggest that behavioral traits, such as oviposition site selection and adult dispersal mode, rather than species composition should be used to understand community assembly. This perspective dovetails the recent interest in assigning functional groupings to species complexes, for example, diversity-ecosystem function studies, by targeting non-taxonomic ecological clusters based on key traits of interest [8]. They go on to make the important point that different traits must be studied at different spatial scales, and emphasize the value of integrating across biological scales. In particular, studies of behavior can inform large-scale processes and vice versa. Like Eubanks and Finke, these authors identify how this information can ultimately improve management, in this case improving stream restoration efforts in anthropogenically altered landscapes.

In the third review Lee A Dyer, Tom L Parchman, Christopher S Jeffrey and Lora A Richards take an extremely broad view of tropical insect community structure, proposing that given current knowledge of chemistry and genomics, we should include chemical and genetic diversity into our characterization of communities, especially hyper-diverse tropical insect communities. That is, the diversity of a multitrophic level community is made up of not just taxonomic but also genetic (both within and among species) and phytochemical diversity. This more diffuse measure of 'interaction diversity' is a better measure of community complexity, productivity and function than classic food webs. Interestingly, this argument parallels those by Heino and Peckarsky in that both push for integration across biological hierarchies that have historically been studied in isolation (i.e., molecular biology, phytochemistry, and trophic ecology). As the authors note, latitudinal gradients in biodiversity have fascinated ecologists since the days of Darwin and Wallace, but a renewed interest in understanding tropical ecosystems and the insects inhabiting them has taken on a sense of urgency given current rates of deforestation.

In the fourth review, Gaylord A Desurmont and Ian S Pearse consider the status of an organism as invasive or native, rather than its taxonomic identity, for its role in a community. With increased globalization and concomitant exchange of species between otherwise isolated ecosystems, invasive plants and herbivores have resulted in novel plant–insect associations in virtually all communities [9,10]. Desurmont and Pearse ask a simple question of both basic and applied relevance: Can we make generalizations about impacts on a community based on the trophic level harboring the exotic species — plant or insect herbivore? Either scenario leads to a native/invasive evolutionary mismatch, with potential downstream consequences for ecological processes such as induced defenses, acquisition of mutualists, and interspecific competition [11]. Importantly, the review contrasts plants and insects along the full spectrum of events leading to invasion, including arrival, establishment, and spread, and the traits facilitating these processes. For instance, the authors make the shrewd observation that insect diet breadth has varying consequences for invasion, with a broad host range elevating the likelihood for establishment but not ultimately affecting invasiveness. That is, the list of our most destructive non-native insect herbivore pests includes numerous cases of both monophagous and polyphagous species. In their review they eventually conclude that introduced plants often have a large direct impact, while introduced herbivores have indirect effects due to their impact on the plants they consume. Unlike the other reviews in this section, Desurmont and Pearse delve into evolutionary factors as an entry point for predicting community-level interactions.

In the final paper, Louie Yang and Claudio Gratton do not consider how a community is described, quantified or assembled, but instead consider the role of the insect community for an ecosystem. Though insects make up a small amount of the biomass of ecosystems in comparison to microbes and plants, they play a measurable and potentially large role in ecosystem processes. Yang and Gratton illustrate how this occurs through direct biomass inputs, as well as by trophic modification of plants and microbes via transformation of detritus, herbivory and predation. They make the nuanced point that insects can have a large effect on nutrient cycling via their roles in shaping the non-insect communities that inhabit an ecosystem. By necessity, this perspective requires an above–belowground vantage point due to the intimate association with microbes and the detrital food web. The authors nicely demonstrate this phenomenon with examples from their own work on resource pulses that quantify the ecosystem-scale consequences of mass emergence of periodical cicadas and aquatic insects (e.g., midges). We found it interesting that this is the third review among the group that stressed the importance of biological integration across disciplines, in this case merging insect community ecology with the microbial world.

The reviews in this section seek to broaden the metrics used to quantify or describe an insect community. Their differing approaches to some extent reflect the research systems used. For instance, it is not surprising that the importance of scale of study is emphasized by Heino and Peckarsky because stream insect communities can only be understood when taking into account both processes occurring locally within a riffle and those happening at a larger scale, such as between streams in a watershed. However, not all types of communities have such discrete issues of scale. The differences in metrics emphasized also reflect the purpose of the research. Dyer and

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colleagues, for example, discuss components of diversity that are central to tropical conservation biology. Notably, each of the perspectives is influenced by the nature of their end-product application, which are quite distinct. The five papers in this section are of both basic and applied interest. They are highly pertinent to sustainable agriculture, restoration, biodiversity conservation, invasive species management, and provisioning of ecosystem services, respectively.

We hope that, despite the superficial differences associated with ecosystem type and research goals, the individual perspectives of each paper are not viewed in a bubble. There is no doubt that each can be overlaid onto multiple communities to foster a better understanding of structure and dynamics. Last, we thank the authors in this section for sharing their unique and novel views of insect community ecology. We learned a lot from editing these contributions and hope they inspire thought for future research efforts geared toward dissecting complex insect communities in diverse ecosystems.

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