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Current Opinion in Insect Science

Editorial overview: Effects of global change on species interactions and biodiversity in natural and managed landscapes

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Current Opinion in Insect Science 2021, **47**:iii–vi

For a complete overview see the Issue

https://doi.org/10.1016/j.cois.2021.09.001

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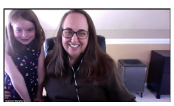

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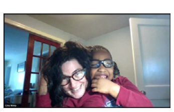
Shannon Murphy is a professor at the University of Denver in Denver, Colorado. Her lab studies the ecology and evolution of plant-insect interactions, with a particular focus on the effects of human-caused global change. Recent projects have investigated the effects of nutrient pollution, wildfire, light pollution, and habitat fragmentation on species interactions and foodweb dynamics. She is passionate about increasing opportunities for underrepresented scientists so that the fields of ecology and entomology in the future will be more diverse, equitable, and inclusive.

Gina M Wimp



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Gina Wimp is an associate professor at Georgetown University in Washington, D.C. Her lab studies the evolutionary factors that promote diversity and the human factors that erode biodiversity. She has worked in three systems: cottonwood riparian forests, intertidal salt marshes, and Eastern deciduous forests. In each of these systems she attempts to build bridges with local, state, and federal stakeholders in order to implement policies that protect biodiversity

Global environmental change is affecting insect species, populations, and communities worldwide. Recently there has been a debate in the literature about whether insect populations are declining precipitously as an ‘insect apocalypse’ [1–4] or if the word apocalypse is an overstatement, since several of the original papers were restricted to specific sites and/or did not account for other disturbances (e.g. Refs. [5,6]). However, the most recent comprehensive meta-analysis suggests that insect populations are indeed declining in terrestrial systems, but results are incredibly variable across ecosystems [7]. Specifically, van Klink *et al.* [7] found that the more precipitous insect declines were found in unprotected, terrestrial systems. While van Klink *et al.* [7] identified overall patterns, they did not examine the mechanisms that might lead to variable responses by insects to global change across different systems. In order to understand whether and how insect populations are changing over time, we need to understand how insects respond to global change drivers in both natural and managed systems, and across a wide variety of habitats.

Each of the articles in this issue examines how species interactions, diversity, and community composition are changing as a result of anthropogenic disturbance. Importantly, these articles examine insect responses to global change in both natural and managed habitats and from a multi-trophic perspective. We have solicited articles on topics that span a large range of elevations and habitats, from agricultural to urban to natural, to understand how global change is broadly affecting insect biodiversity. Importantly, by addressing the mechanisms that impact insect biodiversity across these systems, we may be able to identify general principles that determine species, population, community, and ecosystem susceptibility to global change.

The contribution by Yang, Postema, Hayes, Lippey, and MacArthur-Waltz gives us a broad overview of how complex global change drivers can be, especially when multiple drivers interact. They focus on four general categories of global change (climate change, land use change, novel chemicals, and the increased global transport of organisms) and review how these affect insect behavior, phenology, life histories, distributions, and abundance. These global change drivers have both direct and indirect effects on communities and how they interact to affect species interactions and ecosystem function is only just beginning to be understood. One type of species interaction that is affected by global change is mutualism and Vidal, Anneberg, Curé, Althoff and Segraves review the impact of global change on insect mutualisms. Not only do insects face multiple, interacting drivers of global change (e.g. warming, drought), but

and restore ecosystem function. She actively works to make STEM an inclusive environment and provide opportunities for students from diverse backgrounds.

such changes can disrupt mutualisms if at least one partner in the mutualism is affected. Not all mutualisms will be equally impacted by global change, and those with high levels of specialization or partner dependency are likely to be most strongly impacted. However, when insects are involved in networks of mutualistic interactions, this may buffer the impacts of global change on component members.

Understanding the impacts of global change on species interactions is important because such changes can impact ecosystem services. The contribution by Borchardt, Morales, Aizen, and Toth argues that conserving the ecosystem services provided by pollinators requires a systems-level approach and an understanding of the network of partners involved in plant-pollinator mutualisms. While pollinator networks with generalists are more likely to persist under disturbance due to global change, the authors make an interesting point that even specialists benefit from networks containing generalists. In the case of plant-pollinator mutualisms, a generalist pollinator can maintain populations of the host plant even when the specialist pollinator experiences declines, which allows the specialist pollinator to rebound after disturbance. While arthropod food webs involving living plants have received much more attention, Wu, Niklas, and Sun review how species interactions in detrital systems can also impact the critical ecosystem services provided by decomposers. Moreover, the ecosystem services provided by decomposers can be strongly impacted by global change at the individual, population, and community levels. Warming may affect the metabolism of individual decomposers, population abundance of decomposers, interactions between decomposers and their predators, and can lead to drying of detritus, all of which can alter decomposition rates.

There are many different kinds of global change and three of the articles in this issue focus on a specific driver and what is known about how it affects insect behavior, populations, and communities.

Abarca and Spahn review how insects respond to altered temperature regimes. Specifically, they synthesize the literature on insect responses to thermal stress and how altered temperature regimes create phenological mismatches between insect herbivores and their host plants as well as their natural enemies. Urbanization and human development are increasingly recognized as significant selective pressures for insects and in this issue we have invited two papers that explore insect responses to light and noise pollution. Grubisic and van Grunsven review how artificial light at night affects intra-specific and inter-specific interactions. They highlight how little we actually know about how light pollution affects insect communities and in particular how we lack a theoretical framework for research on artificial light at night. Similar to light pollution, noise pollution seeps out of urban areas and thus affects insects in a wide range of habitats. The review by Classen-Rodríguez, Tinghitella and Fowler-Finn focuses on what we know about how anthropogenic noise alters insect behavior via masking, distraction, and misleading. Further they highlight many common experimental design flaws that hinder our ability to better comprehend the effects of anthropogenic noise and how little we understand about how multiple sensory pollutants (e.g. noise and light) interact to affect insect behavior and interactions.

Articles in our issue also cover a wide range of geographic and elevational habitats from high elevation montane regions to low elevation coastal regions. McCain and Garfinkel demonstrate that insects are indeed tracking climate change; of the approximately 1500 different montane insect populations that have been examined, most have shifted to higher elevations in response to warming. However, the authors stress that studies need to include multiple sampling dates in order to get a better measure of insect seasonal abundance, studies need to include a broader array of taxa (since responses varied across different insect orders), and studies need to be conducted across more geographic locations to understand the variability we find in insect range shifts. At the other end of the elevational spectrum, Rippel, Tomasula, Murphy and Wimp review how global change in marine coastal habitats affects insect populations and communities. There are three main types of global change disturbances that affect these coastal communities (weather events, deleterious inputs, and habitat loss and transformation) and the authors review what is known about how these disturbances directly and/or indirectly affect arthropod foodwebs. Again, the authors highlight here, as has been the case in many other of the articles in this issue, how most research investigates individual disturbances, yet these disturbances interact in complex and unpredictable ways and their multiplicative effects need to be better investigated.

Understanding that insects and plants interact in complex foodwebs can also help improve pest suppression in agriculture and reduce our dependence on pesticides, as reviewed by Zhang, Stephan, Björkman, and Puentes. One group of insects that may aid in pest suppression is omnivores. While insect omnivores are known to serve as natural enemies of agricultural pests, they are also herbivores that can induce plant defenses. These plant defenses can either decrease pest performance on plants or can attract parasitoids that feed on the herbivores via volatile emission. Thus, omnivores can deliver a one-two punch to agricultural pests. While methods of biological control have improved, these methods have also been hampered by our linear view of foodwebs; we often do not consider that there are other organisms living in these habitats besides our species of interest. As reviewed by Montserrat, Serrano-Carnero, Torres-Campos, Bohloolzadeh, Ruiz-Lupión and Moya-Laraño, this can lead to either reductions or increases in pest suppression depending on which organisms are present in the community. Moreover, by understanding that ecology and evolution can act on similar time scales, we may be able to use artificial selection to enhance the success of biological control. When we think of pest species, we often think of agricultural pests, but Koltz and Culler review how climate change is affecting biting insects in the arctic, which have significant negative effects on humans and wildlife. While these biting insects have long been a nuisance in the arctic, climate change is impacting both immature and adult stages via changes in survival, development time, phenology, host seeking activity and interactions with other species. However, arctic insects are relatively understudied, which limits our ability to understand the ecological, evolutionary, and economic impacts of climate change on this important group. In addition to the impacts of warming on insect distributions, global trade has led to the introduction of many exotic species such as ants to new habitats, where they can be terrible pests. The article by Lach reviews how invasive ants present a particular challenge because they can not only displace native ant species, but can induce outbreaks of phloem-feeding pests such as aphids, and directly impact human health and agriculture. Moreover, invasive ants seem able to withstand global change better than their native counterparts because it is their ability to thrive across a range of habitats that enabled their spread as invasive species.

As the first women to be invited as Editors for the Global Change Biology issue in the 8 years that Current Opinion in Insect Science has published this special feature, we felt it was important to invite authors from diverse backgrounds and who are often underrepresented in invited reviews. Women in particular are often underrepresented in invited research forums (e.g. Refs. [8,9]) and we are proud that our authors are 64% women or female-identifying, 85% of the articles were led or co-led by women, and 38% of the articles were authored entirely by women. We would like to note that leading a diverse issue was not challenging as there are so many women doing cutting-edge research on global change, so compilations like ours with adequate gender representation should be the rule, not the exception for publications today. Notably, all of the articles in this issue were written during the COVID pandemic and so it is a huge accomplishment for all of our authors to have made this happen during such a stressful time. Further, many of the authors in our issue are parents who, like us, wrote these pieces while also struggling with online school for their children (as perfectly depicted in our zoom photo). Thus, we are especially grateful for their contributions.

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