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From the lab to the landscape-translational approaches to pollinator health

Editorial Overview: Social insects

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Approximately 90% of flowering plants — corresponding to nearly three quarters of global agricultural crops — use pollinators to set seed and fruit [1,2]. However, populations of several species of pollinators are in decline throughout the world [3–5], threatening the stability of our ecosystems and productivity of our agricultural landscapes.

Three major events from 2006 to 2007 catalyzed global awareness of our dependence on pollinators and the severe and increasing threats to their populations. First, the publication of the US National Research Council's report on the Status of Pollinators in North America [6] cataloged dramatic declines in several managed and unmanaged pollinator species, while highlighting our lack of understanding of the factors that are causing these declines and the surprisingly limited information available for the vast majority of pollinator species. Second, US beekeepers reported heavy and enigmatic losses of their honey bee colonies, a phenomenon soon called Colony Collapse Disorder (CCD) [7]. Third, an international coalition of researchers published the honey bee (*Apis mellifera*) genome sequence, providing critical new tools and approaches for studying honey bee health [8].

These events galvanized the scientific community, stakeholders, policy-makers and the public to work together to conserve and expand pollinator populations. While there have been tremendous advances in our understanding of the status and health of global pollinator populations in the last 9 years, populations of many key species, including honey bees, continue to experience declines. Worldwide attention to the plight of pollinators continues to increase. Indeed, the US Pollinator Health Task Force recently released a sweeping set of US federal policy recommendations generated in response to President Obama's presidential memorandum on pollinators [9], while the EU and member countries have funded a series of pollinator monitoring (e.g., www.COLOSS.org, [5]) and research initiatives.

In this special issue of *Current Opinion in Insect Science*, we have integrated the most recent scientific studies examining the state of global pollinator populations with the key factors impacting pollinator health. We have highlighted the remaining knowledge gaps and threats which must be addressed. Importantly, the reviews in this issue clearly demonstrate how basic scientific research has generated new approaches and recommendations to mitigate pollinator declines, and the critical need for ongoing research to create effective strategies to conserve and expand healthy pollinator populations.

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The events of 2006–2007 made it clear that information about the status of most pollinator populations is woefully limited. Two of the reviews, led by vanEngelsdorp [10] and Meixner [11], discuss results of recent surveys which have dramatically improved our understanding of the status and epidemiology of honey bee losses in the US and Europe, respectively. In addition, Schwarz *et al.* [12] reviews the biotic risk factors tied to worldwide honey bee colony losses. The articles further discuss the importance of national and international monitoring of pollinator populations to both fully document pollinator declines and identify the associated drivers of these declines.

A consensus has emerged that honey bees and other pollinator species face acute risks from three primary stressors: exposure to anthropogenic chemicals, deficient food sources, and new or resurging parasites and pathogens. In addition, many unmanaged, wild pollinator species are vulnerable to natural habitat losses. Biotic risk factors for bee declines are discussed in this issue in reviews led by Flenniken (viruses, [13]), Genersch (bacteria, [14]), Evison (fungi, [15]), Vaudo and Winfree (nutrition and habitat, [16,17]). Abiotic factors, including the impacts of pesticides, pesticide formulations, and how they are applied in the field, are dissected in reviews led by Berenbaum [18], Mullin [19], Krupke [20], and Biddinger [21]. In all cases, the authors identify the key threats, describe the latest advancements in our understanding of how these impact pollinators, and provide recommendations for future lines of research as well as pollinator and land management strategies that can mitigate these threats.

Importantly, many of these stressors act synergistically, and thus it is critical to evaluate the effects of interactions among these stressors and within an ecological and genetic context. Reviews led by Schwarz [12], Evison [15] and Meixner [11] discuss the need to examine and account for interactions between symbiotic microbes, pathogens, parasites, host genetics and different environmental conditions, while DeGrandi-Hoffman and Chen [22] discuss the association between nutritional resources and disease. Moran [23] highlights exciting developments in the field of metagenomics — the application of new technologies and approaches to understand the impacts and evolution of microbes specifically adapted to their bee hosts.

In the case of social insects such as honey bees, examining the effects of different stressors in the context of social organization and colony-level population dynamics is critical to understanding how they can lead to the demise of social unit. The effects of stressors on social dynamics, colony collapse and overwintering success of honey bee colonies is discussed in reviews led by Barron [24] and Doke [25].

Several reviews discuss how recent advances in both techniques and knowledge can be harnessed to conserve and promote healthy pollinator populations. Biddinger and Rajotte [21] discuss the critical need to consider 'Integrated Pest and Pollinator Management (IPPM)' approaches to ensure growers can use an array of tools to sustainably enhance crop production while protecting the ecosystem services provided by pollinators. Advances in our understanding of bee breeding can lead to the generation of more resilient stocks of managed pollinators, as described in a review led by Niño [26]. With massive increases in genomic information for honey bees and other pollinator species, it is now possible to use genomic tools and resources to document population declines, study the factors impacting pollinator health, and develop more resilient stocks of managed pollinators, as reviewed by Grozinger and Robinson [27]. Finally, the new information and recommendations generated by the scientific community can only be effective if supported by social and regulatory frameworks produced by collaborative efforts across policymakers, stakeholder groups, and the public, as discussed by Suryanarayanan [28].

In the past decade, we have made great strides in our understanding of the status and health of global pollinator populations, and in the tools and resources available to examine these issues. These advances have revealed the complexity of conserving and managing species that are threatened by a myriad of interacting biotic and abiotic factors, and demonstrate the need to deploy a 'systems approach' to study pollinator health. Insights provided by these studies have already generated new strategies for better management of pollinator populations and their environments, and these strategies will be further refined and expanded as we address the existing gaps in our knowledge. Forging stronger connections across the scientific community, stakeholders, policymakers and public will ensure healthy agricultural and natural ecosystems through the conservation and expansion of pollinator populations.

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