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Editorial: Insect pollinators in the Anthropocene: how multiple environmental stressors are shaping pollinator health

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Editorial on the Research Topic
Insect pollinators in the Anthropocene: how multiple environmental stressors are shaping pollinator health

Loss of biodiversity, particularly concerning insect pollinators, is a defining feature of the Anthropocene, and may have potentially severe consequences for ecosystem function and food security (Potts et al., 2010). A range of abiotic and biotic stressors, such as habitat destruction and fragmentation, pests and pathogens, climate change, intensified agriculture, poor nutrition, and pollution, are likely responsible for the observed insect declines, including bees and other insect pollinators (Figure 1) (Sánchez-Bayo and Wyckhuys, 2019). These environmental stressors most certainly interact with one another and generate complex effects that amplify individual stressors. There are still knowledge gaps concerning how even the most important stressors may interact to affect insect pollinators. In this Research Topic, we highlight research focusing on how environmental stressors shape pollinator health.

The effects of climate change on insect pollinator health remain poorly understood, but will most likely result in changes to their behavior, physiology, phenology, and distribution (Harvey et al., 2023). Unlike honey bees that can regulate temperature at the colony level, solitary bees are subjected to ambient temperatures in the environment, possibly leaving them more susceptible to the changing climate and extreme weather. Scalici et al. explored how the interaction between temperature and geographical origin affect the fitness of blue orchard bees, *Osmia lignaria*. Developing bees that were reared on temperatures warmer than their native ranges had reduced fitness. Furthermore, developmental differences were observed between populations, suggesting a possible interaction between genetics and environment which may explain how certain populations were better adapted to temperature and environmental change. Such findings are crucial to predict potential

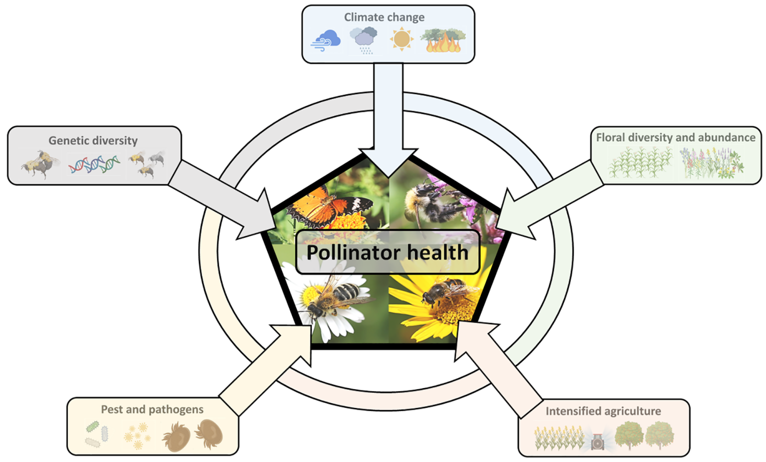

FIGURE 1
Key factors affecting pollinator health in the Anthropocene. Research in this Research Topic addresses how multiple environmental stressors, including climate change, pest and pathogens, genetic diversity, intensified agriculture, and floral diversity and abundance, are shaping pollinator health. Figure created with BioRender.com.

impacts of climate change on insect pollinators, yet they also highlight the urgent need for additional research to improve our understanding.

Many insect populations are especially susceptible to habitat loss and fragmentation (Foley et al., 2005; Potts et al., 2010), as they are dependent on abundant and diverse floral resources (Baude et al., 2016). Agricultural intensification is a key driver in the loss of natural habitats, causing reduced floral diversity and abundance as well as decreasing natural nesting sites (Kremen et al., 2002). Levenson and Tarpy studied conservation habitat in agroecosystems and showed that even small acreages (i.e., <1 acre) of flower cover positively supported bee diversity and abundance in agroecosystem. Bottero et al. further highlighted the important role of habitat heterogeneity when they sampled pollinator taxa across eight European countries and determined that pollinators responded to landscape and climate parameters in taxon- and crop-specific ways. Bee abundance was positively correlated with landscape diversity in oilseed rape fields. Less-intensively managed habitats also positively influenced pollinator abundance. Both studies emphasize habitat restoration to improve resource availability to support pollinator populations. Additional tools to assess bee nutritional health will be needed to identify bee nutritional status. For example, pollen diets can increase biomarkers of oxidative stress in honey bees and thus act as a possible novel tool to assess nutritional deficiencies in bees as shown in Yazlovytska et al.

Pests and pathogens are believed to be a key factor influencing population dynamics of wild and managed bee species (Cameron et al., 2011; Neumann et al., 2012). The ectoparasitic mite, *Varroa destructor*, and its associated viruses remain the greatest threat to apiculture globally (Rosenkranz et al., 2010). To mitigate the negative effects of *V. destructor* parasitism and potential viral spread, effective treatments at the appropriate times are required to prevent further unsustainable losses of managed honey bee colonies (Steinhauer and Saegerman, 2021). Jack et al. revealed that temporal efficacy of mite treatments can vary across seasons, with treatments in winter and spring being more effective at reducing mite populations in colonies compared to treatments in summer and fall. These findings are key in aiding beekeepers to control *V. destructor*, and lay the foundation for future treatments and spatial distribution models. Sobkowich et al. explored the spatial distribution of *V. destructor* infestations in honey bee colonies using a population-level epidemiological approach over a five-year period. They identified a stable cluster of mite infestations with other individual clusters occurring sporadically throughout their study site in Southern Ontario; no link between mite infestation and environmental factors was detected. Mitigating mite populations in managed honey bee colonies will have positive downstream effects for colony health and may also reduce the potential virus spillover to wild bee species (Nanetti et al., 2021). Schauer et al. studied the potential impact of viral spillover from managed honey bees to wild bees and demonstrated that Deformed Wing Virus A (DWV-A) does not replicate in the mason bee, *Osmia bicornis*, and is thus unlikely infectious. Nevertheless, there is a potential that *O. bicornis* may act as a host, as DWV-A recovered 16 days post-microinjection was infectious to honey bees. Besides potential spillovers, pathogens can also interact with environmental pollutants such as agrochemicals. Thebeau et al. showed that concurrent exposure to four fungicide products commonly used in blueberry production may increase honey bee larvae susceptibly to *Melissococcus plutonius*, the causative agent of European Foulbrood. Such findings are essential to improving our understanding of the mechanistic pathways and consequences underlying pesticide and pathogen interactions.

Sustaining insect pollinators in the Anthropocene will require mitigating the multitude of stressors insect pollinators simultaneously encounter. There is still a need to understand how many different environmental factors affect insect pollinators on their own, or in concert. However, it is becoming increasingly clear that providing flower-rich habitats can mitigate the effects of environmental stressors. Altogether, this information will contribute towards decision making processes for environmental management. A framework will need to be developed for pesticide applications in different cropping systems, as microclimate and presence of different bee species in an area needs to be considered prior to pesticide application decisions as discussed in Decourtye et al. Further, Barrett et al. highlight the relevance of keeping a balance between conservation and animal welfare goals when establishing insect pollinator monitoring programs that are key to improving our understanding population dynamics of pollinators.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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