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Preface: Workshop on Pesticide Exposure Assessment Paradigm for *Non-Apis* Bees

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Since the mid-2000s, increased annual losses of honey bee (*Apis mellifera* L., Hymenoptera: Apidae) colonies and declines in some species of non-*Apis* bees have been reported (Biesmeijer et al. 2006, NRC 2007). These losses, particularly with respect to honey bees, have been associated with multiple factors including pesticides, pathogens (viruses, fungi, bacteria), pests (primarily the parasitic mite *Varroa destructor* Anderson and Trueman [Arachnida: Parasitiformes: Varroidae]), poor nutrition, and bee management practices acting in combination (vanEngelsdorp et al. 2008, 2009; Ratnieks *et al.* 2010). Because of the role that bees play in providing pollination services to natural and agricultural-based ecosystems, efforts are underway to understand and mitigate factors associated with global

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declines (IPBES 2016). With respect to the potential role that pesticides may be playing in these declines, regulatory authorities across the continents have collaborated with a range of stakeholders to develop effective means of estimating the risk to bees that is associated with exposure to pesticides.

In January 2017, a workshop was held at U.S. Environmental Protection Agency (EPA) Office of Pesticide Programs in Arlington, Virginia, to address uncertainties with regard to the adequacy of honey bees as a surrogate for assessing exposure of non-*Apis* bees to pesticides. The workshop was a response to informal discussions held by multiple global stakeholders (representing academia, agrochemical companies, and government authorities) at various scientific meetings. Such a meeting was a welcome and relevant progression of a 2011 Pellston workshop (described below). A review of recent published contributions on pesticide risk assessments and notable concerns of international regulatory authorities is provided to lend an understanding of the need for this workshop and its objectives.

In January 2011, a Society of Environmental Toxicology and Chemistry (SETAC) global Pellston workshop convened to synthesize the best available science on exposure and effects assessment methodologies for *Apis* and non-*Apis* bee species and to help define a process for evaluating the risk of pesticides to bees. Consistent with SETAC goals, the workshop proceedings (SETAC 2014) were published in 2014 and included contributions from representatives of five continents with roughly equal representation from industry, academia, and government. The workshop had four main focus areas including the assessment of 1) the exposure of pollinators to pesticides, 2) effects of pesticides on pollinators under laboratory conditions, 3) effects of pesticides under field conditions, and 4) risks to pollinators. An underlying, fifth focus area was to examine the extent to which existing and proposed approaches for assessing exposure and effects on honey bees would be suitable for estimating impacts to non-*Apis* bees. Subsequent to the workshop, regulatory authorities such as the European Food Safety Authority (EFSA), the Australian Pesticides and Veterinary Medicines Authority (APVMA), the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis (IBAMA), Health Canada's Pest Management Regulatory Agency (PMRA), and the EPA continued to evolve their approaches for assessing the potential risks of pesticides to bees. As part of those efforts, EPA, PMRA and the California Department of Pesticide Regulation collaborated to develop a harmonized risk assessment approach that was presented to a FIFRA Scientific Advisory Panel (SAP) in 2012 (SAP 2012).

In the 2012 White Paper (USEPA 2012) describing a harmonized conceptual framework for assessing risk to bees, the honey bee was identified as the focal species because 1) they are considered one of the most important pollinators globally from both a commercial and ecological perspective and 2) standardized test methods for evaluating exposure and effects of chemicals in a regulatory context are more developed for the honey bee compared to non-*Apis* bees. When questioned whether honey bees are reasonable surrogates for non-*Apis* bees, the 2012 FIFRA SAP concurred with the White Paper that honey bees are a reasonable surrogate. However, the SAP noted that other non-*Apis* species may be exposed differently and that EPA should consider testing other commercially available species (SAP 2012).

As noted in multiple agency and interagency documents (e.g., the EPA Bee Risk Assessment Guidance (USEPA et al. 2014), the National Strategy (White House 2015a) document, the Pollinator Research Action Plan (White House 2015b), and the Colony Collapse Disorder and Honey Bee Health Action Plan (USDA 2015), EPA has identified and committed to a process for expanding the methods and data available for evaluating pesticide risks to non-*Apis* bees. Accordingly, EPA is working with its international regulatory and research counterparts (e.g., the Organization for Economic Cooperation and Development (OECD), the International Commission for Plant-Pollinator Relationships (ICPPR), and the Colony Loss Network (COLOSS)) to develop protocols for testing non-*Apis* bees in order to increase the data available for risk assessment of non-*Apis* bees. While these efforts are expanding the capacity to estimate the sensitivity of non-*Apis* bees, similar efforts to understand and document exposure for non-*Apis* bees have lagged.

In response to comments from the SAP on the White Paper and based on the Scientific Opinion developed by EFSA (EFSA 2012), an EPA/PMRA/CDPR-harmonized guidance document for assessing the risk of pesticides to bees was finalized in 2014. For reasons described previously, the harmonized guidance (USEPA et al. 2014) is focused on the honey bee. However, protection of non-*Apis* bees is implicit within the identified protection goals in the harmonized guidance as well as EFSA (2013) and APVMA (2015) guidance documents. In addition, the EFSA guidance considers non-*Apis* bees explicitly, but exposure and effects data are lacking relative to *Apis*. And while there is a significant effort to address the testing protocols for effects data, little effort has been directed towards understanding how non-*Apis* bees might be exposed to pesticides via pathways not represented by the honey bee.

Significant uncertainties exist with regard to exposure pathways for non-*Apis* bees. If non-*Apis* bees are subject to novel pesticide exposure pathways, the honey bee may not be a suitable surrogate with which to estimate potential risk. The exposure pathways for honey bees are considered relatively well understood, with potential exposure via contact with sprays or residues on plants, consumption of contaminated pollen and nectar, water, honeydew, extra-floral nectar, wax, propolis, and guttation fluids. As noted in the harmonized guidance (USEPA et al. 2014), while multiple exposure pathways exist, contact exposure and ingestion of residues on pollen and nectar are considered the predominant routes for honey bees. Exposure pathways for non-*Apis* bees may overlap with those for honey bees, but may also include others, such as exposure of adults or larvae to residues in soil or leaf pieces used for nesting materials. If these alternate exposure pathways are prominent, non-*Apis* bees may face exposure to pesticides in ways not currently addressed in the honey bee assessment guidance, and therefore, effects to these taxa may be underestimated. Currently, non-*Apis* bees can be sorted into three broad categories that include the social non-*Apis* bees, such as bumble bees (*Bombus* spp., Hymenoptera: Apidae) and stingless bees (Hymenoptera: Apidae: Tribe Meliponini), and the solitary bees that represent the vast majority of the non-*Apis* bees, such as alfalfa leafcutting bees (*Megachile rotundata* F., Hymenoptera: Megachilidae), mason bees (e.g., *Osmia lignaria* Say and *O. bicornis* L., Hymenoptera: Megachilidae), and alkali bees (*Nomia melanderi* Cockerell, Hymenoptera: Halictidae). The potential exists that exposure routes differ between honey bees and non-*Apis* bees, because non-*Apis* bee species greatly outnumber *Apis* species and

non-*Apis* bees exhibit large biological, ecological, and behavioral variability. Thus, *Apis* species, specifically honey bees, may not be appropriate surrogates for all species of non-*Apis* bees.

In recognition of the uncertainties that remain for pesticide risk assessment for bees, evaluation of the appropriateness of the honey bee as the primary terrestrial invertebrate used to assess potential risk of pesticides to bees necessitated the workshop that was held in January 2017 that was designed to only address that first level of concern for non-*Apis* bee risks, which is to understand and identify pesticide exposure. Invitees from Europe, Brazil, Canada, and the United States who are experts in non-*Apis* bee biology, ecology, ecotoxicology, and risk assessment distributed over academia, regulators, and industry were assembled with the goal to address the following questions:

- What is currently known about non-*Apis* species and how their life history-traits differ from honey bees in relation to exposure to pesticides?
- What are dominant exposure routes and secondary exposure routes to pesticides for solitary bees and social non-*Apis* bees?
- Can such routes of exposure be readily quantified/estimated empirically (e.g., consumption rates of pollen and nectar for all bee ages, contact rates via leaves/mud in nests, etc.) in the same manner as for honey bees (e.g., in BeeRex model; USEPA 2015)? If so, how well are these estimates covered by those used for honey bee risk assessments?
- If non-*Apis* bees were to be included in the pesticide risk assessment for estimating the exposure, what are the most suitable surrogates* for solitary bees and social non-*Apis* bees? (*Selection should consider availability, ability to thrive under laboratory conditions; suitability for measuring exposure and effects at individual and population levels, and ability to extrapolate effects from individual to population, etc.)
- What research needs to be conducted to sufficiently and quantitatively answer all the above questions?

Anticipated deliverables from the workshop included a transparent overview of the current state of science related to evaluating pesticide exposure for non-*Apis* bees that could be published in a peer-reviewed journal. This overview would provide valuable input into global regulatory processes. Answers to the questions identified in advance of the workshop were expected to also provide a means for reducing uncertainties in the current practices in the pollinator risk assessment, such as:

- Is the honey bee a good surrogate for evaluating exposure for other bees (non-*Apis* social and solitary bees), and if not, what are the best surrogates for non-*Apis* social and solitary bees?
- How should the exposure for identified surrogates for other bees be assessed?
- What are existing gaps and research needs for a better exposure estimation?

Toward addressing these questions, experts at the workshop focused on each of three major groups of non-*Apis* bees: bumble bees (*Bombus* spp.), solitary bees (e.g., *Osmia* spp., *Megachile rotundata*, *Nomia melanderi*), and stingless bees (Tribe Meliponini). Summary documents on the biology and potential exposure routes for each of the three non-*Apis* bee groups were produced in advance to facilitate discussions during the workshop and have been further developed into separate scientific papers. Deliberations at the workshop focused on identifying exposure pathways for non-*Apis* bees that were not considered to be adequately addressed by honey bee pathway assessments. Subsequently, methods for quantifying exposure of non-*Apis* bees via these unique pathways were explored. The papers that follow this introduction report on the logistical details, discussions, and synthesized outcomes of the workshop delivered in standalone documents. Table 1 lists workshop participants and their affiliations.

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Table 1.**Workshop participants**

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