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Comparative Trapping Efficiency to Characterize Bee Abundance, Diversity, and Community Composition in Apple Orchards

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ABSTRACT Bees are important pollinators of numerous crops, and monitoring their abundance and diversity in commercial agricultural ecosystems is of increasing importance due to pollinator declines. In season-long field studies conducted in Pennsylvania during 2011–2013, we evaluated five different bee monitoring passive traps—three pan traps (blue, yellow, and white) and two vane traps (blue and yellow)—for their effectiveness and utility for monitoring bees in commercial apple orchards. Traps were placed prebloom and were monitored weekly until the end of crop season (mid-October). We recorded 14,770 bees comprising 118 species, 27 genera, and five families. The most abundant species were *Augochlora pura* (Say) (34.4% of total), *Ceratina calcarata* Robertson (15.5%), *Bombus vagans* Smith (7.8%), *Bombus impatiens* Cresson (6.4%), and *Apis mellifera* L. (4.3%). Bee abundance was highly variable among trap types across the three years and during the bloom and postbloom period. Blue vane traps were found to be the most effective trap type, with significantly higher rates of per-sample species accumulation than all other traps. Species richness estimates were highest for the blue vane and blue pan traps. This study reveals the utility and effectiveness of various traps for studying abundance and diversity of pollinator bees in commercially managed apple orchards. It also provides baseline information about the bee community found during the bloom and postbloom periods in Pennsylvania apple orchards that can be used to measure changes in bee community structure and abundance due to conservation efforts, such as reduced risk IPM programs, habitat management, and augmentation.

KEY WORDS bee, pollinator, monitoring, pan trap, vane trap

Bees (Hymenoptera: Apoidea: Anthophila) are the most important pollinators of angiosperms, including important agricultural crops (Klein et al. 2007, Eilers et al. 2011). Except for the honey bee and some bumblebees, bee population declines have not been well documented. Nor have characteristics such as diversity, abundance, and community composition within specific localities been detailed. The recent decline in honey bee populations, loosely termed Colony Collapse Disorder (CCD), has brought increased focus on the fate and utility of the other 4,000 or so species of bees in North America as bioindicators of environmental health and alternative pollinators to supplement or even replace honey bees as pollinators of certain crops.

Apple (*Malus domestica*) is one of the pome fruit crops that is dependent on bees for pollination and is widely grown in temperate regions of the world. The majority of apple cultivars are highly dependent on cross-pollination provided by various bees and other flower-visiting insects (Free 1964, Delaplane and Mayer 2000, Tepedino et al. 2007, Marini et al. 2012). Growers either rent commercially available managed pollinators such as honey bees (*Apis mellifera*), Japanese orchard bees (*Osmia cornifrons*), and bumble bees (*Bombus spp.*), or depend on various species of wild and solitary bees (e.g., *Andrena*, *Ceratina*, *Halictus*, *Lasioglossum*, *Osmia*, *Bombus* etc.), syrphid flies, and other flower-visiting arthropods to ensure adequate fruit set (Boyle and Philogene 1983; Gardner and Ascher 2006; Biddinger et al. 2011, 2013a; Donovall and vanEngelsdorp 2010; Joshi et al. 2011; Ritz et al. 2012; Park et al. 2012).

Populations of pollinator bees in agricultural ecosystems have been declining due to various interacting stressors, such as pesticide use, bee parasites and diseases, reduced availability of diverse floral resources, and loss of appropriate nesting habitats (Oldroyd 2007, VanEngelsdorp et al. 2007, Pettis et al. 2013, Steinhauer et al. 2014). Decline of pollinator populations threatens global food security and agricultural sustainability (Klein et al. 2007). The President of the

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