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SHORT COMMUNICATION

Potential Bias in Pan Trapping as a Function of Floral Abundance

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Pollinators are an important component of ecosystems and provide pollination services to many flowering plants, with a majority of those services being provided by bees (Kearns *et al.*, 1998; Lundberg and Moberg, 2003). Concern over pollinator declines has increased in recent years (Allen-Wardell *et al.*, 1998; Biesmeijer *et al.*, 2006), especially with the identification of colony collapse disorder in managed honey bee colonies (vanEngelsdorp *et al.*, 2007). Pollinator declines have been attributed to several factors, including habitat fragmentation and loss, invasive species, and pesticides (Allen-Wardell *et al.*, 1998; Spira, 2001; Biesmeijer *et al.*, 2006). However, population trends in bee communities have been difficult to document because of fluctuations in bee populations among years (Roubik, 2001; Williams *et al.*, 2001), and the lack of standardized methods for collecting population and community level data (Williams *et al.*, 2001; LeBuhn *et al.*, 2003).

Pan traps, plastic bowls filled with soapy water, are commonly used to passively sample insect communities, particularly bees. Pan traps are often the method of choice because of their efficiency, lack of observer bias, and cost effectiveness (Westphal *et al.*, 2008; Wilson *et al.*, 2008). Although passive sampling often reduces observer/collector bias (Westphal *et al.*, 2008), it is subject to other biases (Droege *et al.*, 2010). For example, pan traps often fail to capture larger bodied bees, such as bumble bees and carpenter bees, and collect other bees less frequently than expected based on their perceived abundance (e.g., honey bees and plasterer bees; Toler *et al.*, 2005; Roulston *et al.*, 2007; Wilson *et al.*, 2008). Pan trap effectiveness also may vary with the availability of floral resources, with effectiveness decreasing with increasing floral resource availability (Cane *et al.*, 2000; Mayer, 2005; Roulston *et al.*, 2007; Wilson *et al.*, 2008). However, no studies have directly assessed the influence of floral resource availability on pan trap effectiveness. Thus, caution has been urged when using pan traps to compare sites or time periods with different levels of floral resource availability (Cane *et al.*, 2000; Roulston *et al.*, 2007; Wilson *et al.*, 2008). We evaluated the effect of floral resource availability on pan trap effectiveness using two different approaches. First, we evaluated the effect of floral removal on pan trap effectiveness. Second, we compared pan trap data between years with low and high floral abundance.

Materials and Methods

Our study sites were located at the Marvin Klemme Research Range (MKRR) and the Stillwater Research Range (SRR). The MKRR is located approximately 15 km South of Clinton in west-central Oklahoma and is predominantly a mixed-grass prairie. We used the MKRR to evaluate pan trap effectiveness at sites with and without floral resource removal via herbicide applications. An aerial application combining 2,4D (*2,4-Dichlorophenoxyacetic acid*), picloram, and Ally® XP herbicide (0.7 kg acid equivalent/ha) was applied 15 May 2009. Herbicide applications reduced forb species richness by 63.6%, 100%, 88.9%, and 83.3% during June, July, August, and September, respectively, within the study plots. Forb abundance also was reduced by >95% each month in the herbicide treated plots. Four separate pastures (two treated with herbicide and two untreated controls) ranging in size from 40 to 50 ha were sampled at the MKRR, with two sampling areas located a minimum of 200 m apart in each pasture.

The SRR is located approximately 21 km southwest of Stillwater in north-central Oklahoma and is predominantly a tallgrass prairie. We used the SRR to evaluate the effect of low and high floral resource availability generated by annual variations in precipitation on pan trap effectiveness. 2006 was a drought year with 30.5% less rainfall than normal based on the 30 year average from 1971–2000, whereas 2007 was a wet year with almost twice as much rainfall as normal (data obtained from a Mesonet station located on the SRR; http://www.mesonet.org/). Although no formal estimates of floral resource availability were recorded, flower resources were very limited in 2006 and abundant in 2007 (KAB, pers. obs.). Three separate pastures

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ranging in size from 45 to 65 ha were sampled at the SRR over a two year period. As part of a separate study, each pasture was divided into six subplots, with one subplot being burned every spring and one subplot being burned every summer. For the purposes of this study, bees were sampled in each subplot and data were combined to represent a pasture level estimate of bee species richness and abundance.

Bees were sampled within a 1 ha area (100 m by 100 m square) at each sampling location (LeBuhn *et al.*, 2003). Sites were sampled once a month from June through September of 2009 at the MKRR and once during July 2006 and 2007 at the SRR. Two transects were established that extended to the corners of each sampling plot and crossed in the center forming an X. Pan traps, 6 oz Solo© white plastic bowls painted fluorescent yellow, blue, or left white, were placed every 10 m along each transect, alternating colors. Different species are attracted to different colors and the selected colors have been identified as the most effective at capturing bees (Toler *et al.*, 2005). The pan traps were filled with soapy water, with the soap serving to break the surface tension of the water and prevent bees from flying off the traps. Traps were placed within each sampling plot before 0900 hours CDST and collected after 1500 hours. Bees were stored in 70% ethyl alcohol until being identified to species or morphospecies using Michener *et al.* 1994 and Mitchell 1960, 1962, and voucher specimens were retained in the reference collection of K. A. Baum.

The abundance and species richness of bees collected in the pan traps were compared among treatments (i.e., herbicide and control) and years (i.e., 2006 and 2007). A two-way repeated measures Analysis of Variance was used to compare treatments and months at the MKRR, followed by multiple comparisons using the Holm-Sidak method. A paired *t*-test was used to compare years at the SRR. Because the power of the paired *t*-tests was low due to small sample sizes (0.522 for bee species richness and 0.425 for bee abundance), effect-size correlations were also calculated based on the original means and standard deviations. The significance level was set at $\alpha = 0.05$ for all analyses.

Results

Thirty species and 1363 individual bees were collected at the MKRR, and 25 species and 3610 individual bees were captured at the SRR. Bee species richness differed between herbicide and control sites ($F_{1,3}$ = 11.221, P = 0.044; Fig. 1), with more bee species collected in the herbicide treated sites (t = 3.350, P = 0.044; Fig. 1). Bee abundance did not vary between treatment and control sites ($F_{1,3}$ = 0.467, P = 0.467; Fig. 1). Species richness varied with month ($F_{3,3}$ = 4.308, P = 0.038; Fig. 1), with more bee species collected in July than June (t = 3.434, P = 0.007; Fig. 1). Abundance also varied with month ($F_{3,3}$ = 14.420, $P < 0.001$; Fig. 1), with significantly more bees collected in July compared to June, August, or September (t = 5.732, $P < 0.001$; t = 3.978, P = 0.003; t = 5.652, $P < 0.001$, respectively).

The number of bee species collected with pan traps did not differ significantly between the dry year (2006) with low floral abundance and the wet year (2007) with high floral abundance (t = 3.897, d.f. = 2, P = 0.060; Fig. 2). Bee abundance also did not differ significantly between years (t = 3.376, d.f. = 2, P = 0.078; Fig. 2). However, effect-size correlations were high for both bee species richness and bee abundance between years (r = 0.873 and 0.8107, respectively), indicating large difference effects.

Discussion

The effectiveness of pan traps varied among sites with and without floral removal for bee species richness but not abundance (Fig. 1). These data suggest an inverse relationship between pan trap effectiveness and floral resource availability, with the strength of the relationship varying among sampling periods (i.e., months). These results support previous studies that suggest pan traps undersample bee species richness when floral resources are abundant (e.g., Cane *et al.*, 2000; Mayer, 2005; Roulston *et al.*, 2007; Wilson *et al.*, 2008).

Pan trap effectiveness did not differ significantly among years with high and low floral resource availability (Fig. 2). However, given the low power of the statistical tests due to small sample sizes, existing differences may not have been detected, and high effect-size correlations suggest these differences are relevant. Thus, the differences in bee species richness and abundance between years are likely biologically relevant to the sampling of bee communities. However, we can not exclude the possibility that bee species richness and abundance may have differed between years because of high bee mortality during the dry year, or that other factors contributed to the observed patterns. Also, inherent variability common in bee populations and communities could have influenced the results (Roubik, 2001; Williams *et al.*, 2001).

Cane *et al.* (2000) proposed several explanations for pan trap ineffectiveness, including height of the pan traps in relation to flower height, flowers being more attractive to bees than pan traps, and color biases associated with preferred flowering species. Bee foraging behavior also may contribute to the inverse

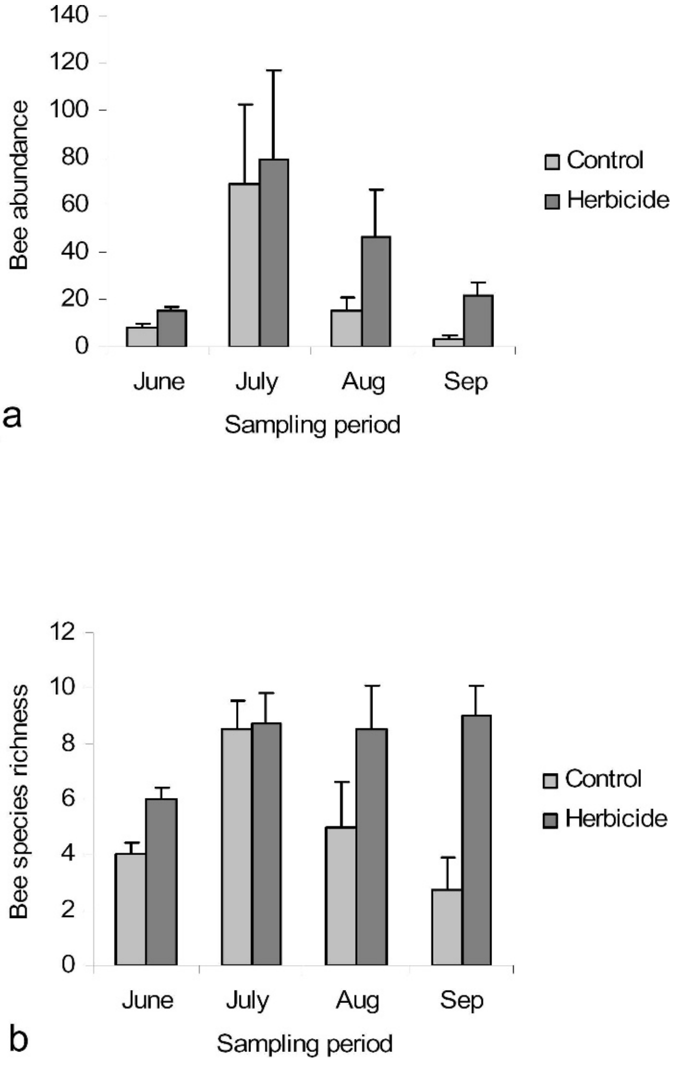

Fig. 1. Bee abundance (a) and species richness (b) (mean ± SE) in pan traps deployed in herbicide treated areas (n = 4) with reduced levels of floral resource availability and control areas (n = 4) with normal levels of floral resource availability.

relationship between floral resource availability and pan trap effectiveness. When floral resources are abundant, bees may not travel as far or spend as much time searching for resources as when floral resources are scarce. Therefore, bees may be less likely to encounter pan traps when floral resources are abundant and more likely to encounter pan traps when floral resources are scarce.

Pan traps may undersample bee species richness and abundance when floral resources are abundant, biasing estimates of species richness and abundance and bringing into question the accuracy of comparisons among sites and years when variability in floral resource availability is high. This bias could be addressed by incorporating estimates of floral resource availability into bee diversity studies, which would provide data needed to evaluate the validity of comparisons among sites and years. Data collected across multiple years with varying levels of floral resource availability will provide the most complete view of bee diversity.

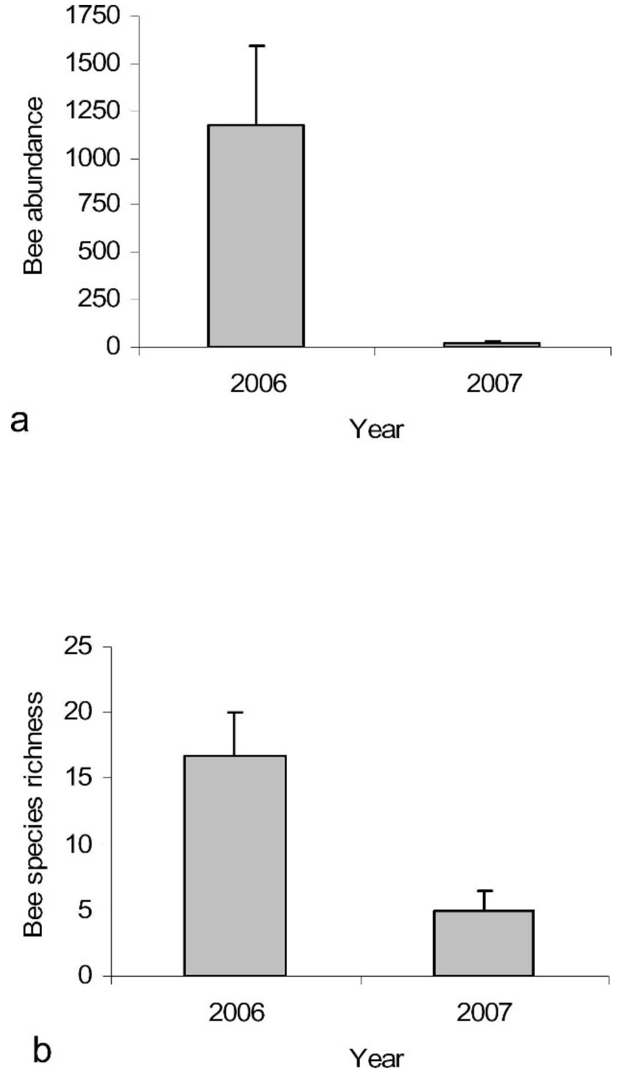

Fig. 2. Bee abundance (a) and species richness (b) (mean ± SE) in pan traps deployed at three sites during 2006 (dry year with scarce floral resources) and 2007 (wet year with abundant floral resources).

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