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SHORT COMMUNICATION

Sampling bee communities using pan traps: alternative methods increase sample size

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Abstract Bees play an important role in natural and agricultural landscapes and increased interest in these pollinators has lead to an increase in studies designed to monitor bee populations across the globe. Many studies investigating bee diversity use pan traps (colored plastic bowls filled with soapy water) as a cost-effective trapping method. Here we investigate how alternative pan trap designs (both the size of the traps, and the addition of "nectar guides") affect the number of specimens collected. We find that larger pan traps collect more specimens than small and medium sized traps, and that the addition of "nectar guides" can significantly increase the number of specimens collected. Increased sample sizes can lead to a better understanding of patterns of bee diversity, which can lead to more informed management decisions.

Keywords Bee declines · Trapping methods · Pan traps · Bowl traps · Nectar guides

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Introduction

Public awareness of bees and the important pollination services they provide has grown dramatically in recent years due in part to several recent studies that have shown dramatic declines in a variety of bee species (e.g., Byrne and Fitzpatrick 2009; Potts et al. 2010; Cameron et al. 2011; Burkle et al. 2013; Goulson et al. 2015). This increased awareness has driven various efforts to document bee faunas in North America (e.g., Messinger 2006; Wilson et al. 2009; Wilson et al. 2010; Sheffield et al. 2013; Hung et al. 2015). Many bee studies rely heavily on collections using pan traps (colored plastic bowls filled with soapy water), because pan trapping is viewed as an attractive alternative to traditional net collecting that is cheaper, requires fewer man-hours, is not dependent on trained collectors, and presumably eliminates collector bias (e.g., Westphal et al. 2008; Gonçalves and Oliveira 2013). Several studies, however, have shown that pan traps have their own biases (i.e., some species are overrepresented in pan traps while others avoid these traps and different colored traps collect different suites of bees) that need to be taken into account when designing collecting methods (Leong and Thorp 1999; Cane et al. 2000; Toler et al. 2005; Roulston et al. 2007; Wilson et al. 2008). Despite these biases pan trap collections can be useful for standardized comparative studies or for cost effective faunal surveys.

Pan traps may be effective at collecting bees because they mimic flowers. Most of the research into pan trap methods has focused on the effect of color, finding that using three colors (white, fluorescent yellow, and fluorescent blue) collects a richer bee fauna than any single color (Cane et al. 2000; Wilson et al. 2008).

In addition to investigating color, some preliminary studies investigated bowl size, finding that the size of bowls has no

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effect on the number of bees collected (Droege 2005). While these findings have caused many researchers to reduce the size of their pan traps in order to minimize the amount of water needed to run a transect of traps, we have observed that larger bees often seem to avoid smaller pan traps and that bees in general avoid pan traps that are 'full' of captured bees (though these observations have not been quantified), so we would expect smaller pan traps to collect fewer and smaller bees. Other investigations found that bowls with UV patterns painted on them to resemble flowers did not increase the number of bees collected (Droege 2005). These results are surprising since most flowers exhibit contrasting colors on their petals, which are thought to act as guides to potential pollinators (Sprengel 1793; Leonard and Papaj 2011), so it would be expected that pan traps with similar patterns would attract more bees.

Because these preliminary studies performed in eastern North America (Droege 2005) appear inconsistent with our observations in the field from western North America, we set out to re-examine these alternative pan-trapping methods. Here we present our results of trials comparing bee abundance collected in three sizes of pan trap, as well as an experiment investigating the effect of contrasting patterns drawn at the bottom of the bowls (nectar guides). Our findings suggest that these alternative methods significantly increase the sample size of bees collected in pan traps.

Materials and methods

This study was conducted in Tooele County, Utah, near the Utah State University campus (40.525° N 112.327° W) from July through September. The study investigating pan trap size was performed in 2012 and the study investigating nectar guides occurred in 2013. While it is clear that using three pan trap colors is preferable (Wilson et al. 2008), all of our trials were conducted using only fluorescent yellow pan traps so we could isolate the variable of interest (pan trap size or nectar guides) independent of color. All traps were deployed in Great Basin shrub-steppe habitat where sagebrush and grasses dominated. In each experiment, pan traps were spaced ~5 m apart because previous studies found that traps separated by this minimum distance did not interfere with each other (Droege 2005).

Effect of pan trap size on bee abundance and bee size

To determine how the size of the bowls affected the number of bees collected we designed transects containing 15 pan traps. A total of 5 transects were deployed. Each transect contained three sizes of bowl; five large (20 oz), five medium (8 oz), and five small (3.5 oz). Bowls were arranged in a sequential pattern rather than randomized to avoid two of the same treatment being arranged next to each other as recommended in the guidelines for pan trapping (Droege 2005). Each transect was deployed from 900 to 1600 h. Bees were collected from individual bowls and were labeled according to the size of bowl they were collected in. Total body length of each bee specimen was measured using a transparent ruler.

For statistical analyses, we only included pan traps that captured at least one bee ($N=67$). We implemented generalized linear mixed effect models (GLMMs) in the lme4 package (Bates et al. 2015) in R (R Core Team 2015) to investigate the effects of pan trap size on both bee abundance and average bee size per bowl. In both models, trap size served as a fixed effect and transect was designated as a random effect. We utilized a Poisson family for the bee abundance model and a Gamma family for the average bee size model. The significance of fixed effects was inferred using a Type II Wald χ^2 test using the car package (Fox and Weisberg 2011) in R. For models with significant fixed effects, differences among treatment groups (i.e. bowl sizes) was assessed with post hoc Tukey tests using the *glht* function in the multcomp (Hothorn et al. 2008) package in R.

Because individual bowls within a transect might not be statistically independent from one another (i.e. pseudoreplicated), we also conducted statistical tests using the average number of bees caught per bowl size per transect and the average bee size per bowl size per transect. These variables served as response variables in a mixed effects model, with bowl size and transect (as a random factor) as predictor variables. Significance of fixed effects was inferred as described above.

Effect of nectar guides on bee abundance

To determine how the addition of nectar guides affected the number of bees collected we designed transects containing 10 pan traps, five with nectar guides and five without. In these transects, 8 oz fluorescent yellow pan traps were used because they are one of the most common sizes of bowls used. Bowls were arranged in an alternating pattern (a blank bowl, a nectar guide bowl, a blank bowl, etc.) rather than randomized to avoid two of the same treatment being arranged next to each other as is a common practice in the guidelines for pan trapping (Droege 2005). Each transect was deployed from 900 to 1600 h. A total of six transects were deployed. "Nectar guides" were added to the bottom of the bowls using a black permanent marker and consisted of six bisecting lines (as in the shape of an "*"). The black permanent marker did not reflect visible light or UV light and it absorbed light across wavelengths from ~200–650 nm. Measurements were made using an Ocean Optics USB2000+ Spectrometer with PX2 Xenon lamp to measure reflectance and a Nanodrop One Spectrophotometer in UV–Vis.

Samples were collected from each pan trap type (with nectar guides or without) and were pooled for each transect. Bees were pooled in this experiment rather than collected from each individual bowl as above due to limited time and personnel resources. We used a paired *t*-test in R to test if pan traps with or without nectar guides captured more bees per transect.

Results and discussion

Effect of pan trap size on bee abundance

The five transects designed to test the effect of pan trap size yielded a total of 283 bee specimens ranging from 4 to 15 mm in body length. On average, large bowls collected 5.9 bees ($SD = 4.51$), medium bowls collected 3.2 bees ($SD = 1.92$), and small bowls collected 3.6 ($SD = 2.01$). While previous studies have suggested that different bowl sizes collect the same numbers of bees (Droege 2005), our results disagree with these findings. We found a significant effect of pan trap size on bee abundance (Type II Wald $\chi^2 = 22.41$; df = 2; $P < 0.001$). Specifically, post hoc tests revealed that larger pan traps (20 oz) collected significantly more bees than medium bowls and small bowls (Fig. 1a; Table S1). The average size of bees collected in large pan traps was 8.13 mm ($N = 130$; $SD = 2.76$), in medium was 7.52 mm ($N = 77$; $SD = 2.63$), and in small was 7.25 mm ($N = 76$; $SD = 2.02$). We did not find a significant effect of pan trap size on the average bee size per trap (Type II Wald $\chi^2 = 5.21$; df = 2; $P = 0.074$; Fig. 1b). When both analyses were conducted using mean values per bowl size per transect (to avoid potential pseudoreplication), the results were qualitatively identical (Table S2), suggesting that non-independence between bowls are not driving these results.

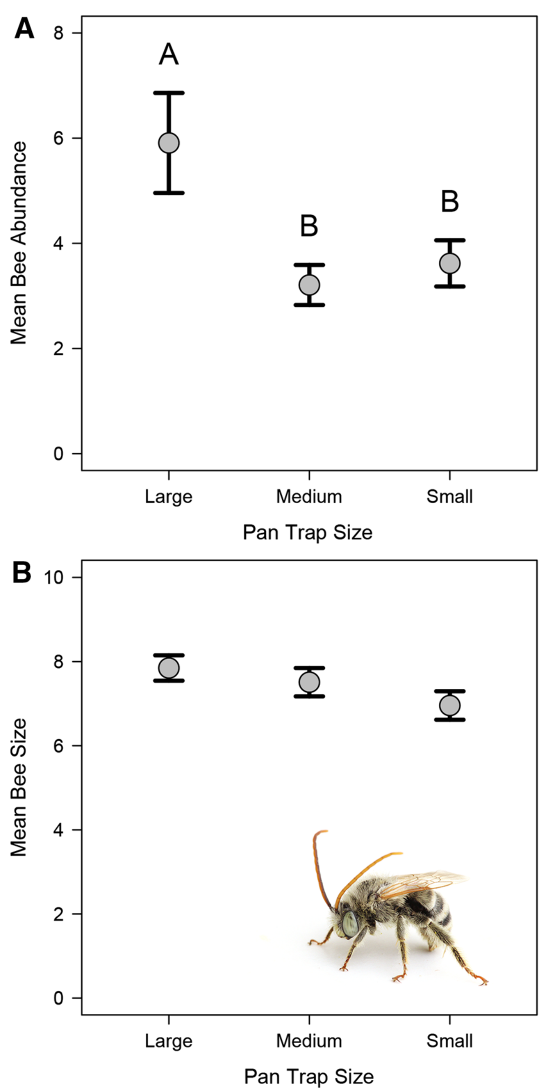

Fig. 1 **a** Plot showing the mean bee abundance and standard errors per bowl in the three pan trap sizes: large (20 oz), medium (8 oz), and small (3.5 oz). Results of the Tukey test are indicated with the *A* and *B* above each box plot with different *letters* indicating statistically different groups. **b** Plot showing the average bee size in each of the three pan trap sizes

Effect nectar guides on bee abundance

The six transects designed to test the effect of nectar guides yielded a total of 504 bee specimens, 332 from bowls with nectar guides and 172 from traditional bowls. In each transect, bowls with nectar guides collected an average of 254 % more bees than did standard bowls. Our results clearly show that pan traps with nectar guides collected significantly more bees than traditional bowls (paired $t = 3.25$; df = 5; $P = 0.023$; Fig. 2). These results clearly demonstrate that traditional pan trap methods could be improved by adding nectar guides at the bottom of the bowls. As with our findings of the effect of bowl size, our results of the nectar guide trials differ from the findings of previous experiments

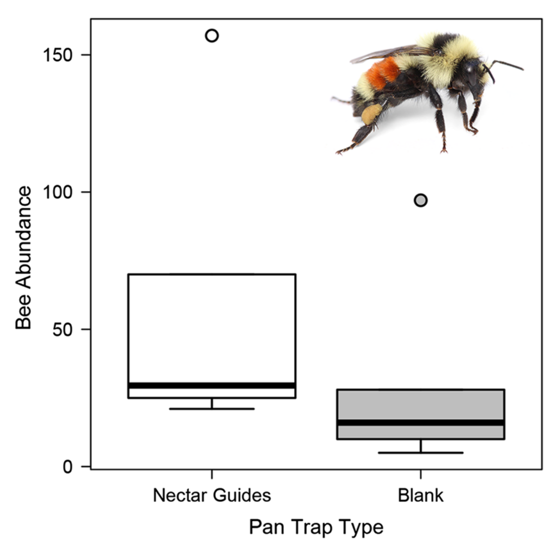

Fig. 2 Plot showing the bee abundance per transect in each of the pan trap types, with nectar guides and blank

(Droege 2005). Differences in our results could be related to the method of adding nectar guides to bowls. Droege (2005) drew patterns with white fluorescent paint on dark blue bowls while we used black lines drawn on fluorescent yellow bowls. Or, as mentioned above, previous trials were conducted in eastern woodlands rather than in western deserts, so the distinct bee communities in their two regions may respond differently to the presence of nectar guides.

Conclusion

Our findings clearly suggest that the alternative pan trap methods examined here (particularly larger bowl sizes and the addition of nectar guides) have the potential to dramatically increase sample size in faunistic studies of bees. Increasing sample size can be useful if limited sampling events are made. Furthermore, increased sample sizes can potentially lead to the collection of more rare bees. These larger sample sizes however, could possibly have a negative impact on bee communities so we suggest additional research should be done before these alternative methods are widely implemented.

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