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Comment

Documenting bee decline or squandering scarce resources

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Introduction

Declining bee populations are a serious threat to pollination, an ecosystem service indispensable to many crop plants and native vegetation (bees are the chief pollinators of angiosperms) (Klein et al. 2007; Gallai et al. 2009; Garibaldi et al. 2013). Convincing evidence of a broad decline in bee abundance and diversity would support conservation actions to reverse such a trend. Recently, LeBuhn et al. (2013) used prospective power analysis to design a worldwide pan-trapping program (LeBuhn et al. 2003; Westphal et al. 2008) to detect a 2–5% annual decline in non-domesticated bee numbers and species richness over 5 years. At a time when conservationists seek to publicize the plight of bees, a monitoring proposal that will kill 1.3 million bees (LeBuhn et al. 2013 [their Appendix S2]) and untold numbers of nontarget arthropods should have a sampling design that is based on transparent supporting data, has clear cost estimates, and has an objective to wring systematic and ecological information from collected specimens. Although we strongly support efforts to conserve bees, we are skeptical that the proposed program meets these sampling requirements. Our criticisms are directed at the limitations of the data used in the power analysis, the program design and timeline, its costs, and, especially, the likely usefulness of the results.

Power Analysis

Given the large differences in diversity of bee communities around the world (Michener 1979), the appropriateness of applying power analysis to "regional, national, or international monitoring programs" based on 3 unpublished pan-trap studies from a circumscribed area of California and Mexico is questionable. To determine the number of sampling sites needed to establish a decline in bee numbers or species richness, LeBuhn et al. used a geometric model of population growth with 3 stochastic parameters: x_t, δ_t, and e_{np} (their Eq. 1, p. 115). Valid power analysis requires realistic estimates of the coefficient of variation (CV) for total abundance (which determines e_{np}), the CV for trend in total abundance among plots (which determines δ_t), and the initial population size x_t (Gibbs et al. 1998). Because CVs are inversely related to power, smaller CVs decrease the estimated number of sites needed to detect declines and thereby reduce projected study costs. It is thus unsettling that Lebuhn et al. used a detrended CV for total abundance (31.22%) that is well below any CV recorded for any of 7 arthropod groups reported by Gibbs et al. (1998) (range 50–131%, mean = 80.1%). LeBuhn et al.'s detrended CV was obtained by averaging across transects, dates, sites, years, and studies and thereby ignored, or smoothed, pertinent spatial, temporal, and regional variation (LeBuhn et al.'s Fig. 2). As reported in Methods, the CV they used for population trend in simulations was 2.05%, which is improbably small. To address the issue of low CVs, LeBuhn et al. ran simulations with error estimates that were 50% higher than their initial estimates, but even these seem small compared with expected values from other studies cited above. Realistic error estimates would be larger and would increase the number of sites needed and attendant costs. Further, CV values are affected by differences among studies in sampling and processing protocols such as number of transects or dates sampled or

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level of taxonomic identification. As such, CV values used in prospective power analysis should come from studies with concordant procedures that reflect the protocols of the planned study; it is unclear that LeBuhn et al.'s 3 pan-trap studies do so.

Complicating our evaluation of the program is their use of several estimates of the expected mean number of bees per site per year. The initial value used in simulations, 375.1 total bees (0.48/pan/day by their protocol), is extremely low, is based on unpublished, part-year studies, and differs from every other total they present. After citing unpublished estimates of 2.3–3.2 bees/pan/day (western United States) and 0.5–1.0 bees/pan/day (eastern United States), which, under their sampling protocol project to 390–2496 bees/site/year, LeBuhn et al. unexpectedly suggest that each site could yield 5000 bees/year (6.4 bees/pan). In contrast, costs were calculated using an estimate of 4.0 bees/pan, or 3120 bees/site/year, a number that appears ex nihilo (their Appendix S3). There is no explanation for these disparate forecasts of average numbers of bees captured per year or why one estimate was used in simulations and another in cost projections.

Program Design

The sampling design of 26 biweekly samples is unrealistic; it is too cold from November to March in most of the world's temperate regions for adult bee activity or plant flowering. Conversely, in the humid tropics or subtropics, pan traps are ill-suited to sampling because of dense vegetation; other, not directly comparable, sampling methods are warranted (Roubik 2001). Realistically restricting sampling to the holarctic from April to October would entail less effort and would be cheaper.

The stated objective of their program is to document significant declines in 5 years, rather than the 10–20 years usually required. However, the study design—each of the 200 sites sampled twice, at 5-year intervals, with staggered sampling of 40 sites each year—ensures a minimum of 10 years to complete the study (9 years for sampling, 1 year for analysis). Thus, time savings is minimal and conservation actions are postponed for over a decade.

LeBuhn et al. are ambivalent about the level of taxonomic resolution to aim for. Their test for decline in species richness (p. 114) shows the importance of species level identification, as does the estimation of costs (p. 117, their Appendix S3). However, subsequently (p. 117–118) they advocate the employment of novices to sort unpinned and unlabeled bees to genus or morphospecies because "identifying bees to species . . . is time-consuming," costly, and taxonomic experts are few and engaged elsewhere.

Such a minimal identification approach is ill-advised; whereas novices may be trained to sort some bees to genus, they cannot be expected to consistently sort a large diverse collection to morphospecies or to reliably pair the genders of a species, and this undermines important objectives. Forgoing species identifications precludes meaningful testing for declines in species richness. Bee abundance and species richness vary at all spatial scales and responds to environmental change in unpredictable ways (tropical bees: Roubik 2001; Samejima et al. 2004; desert *Larrea* bees: Cane et al. 2006; bumble bees: Cameron et al. 2011). Without species identifications and site replication, how will real declines be distinguished from chance declines? How will species whose numbers are dwindling be distinguished from their congeners or species distributions be delimited among sampling dates, years, and sites, and how, through use of the literature, will their ecological characteristics be associated? Without specimen identification, the proposed monitoring effort would devolve into an exercise in bee removal whose subjects lie underutilized in museum drawers.

Costs

Although LeBuhn et al. estimate costs of laboratory labor, there is no explicit estimate of field labor costs (i.e., for setting out and collecting pan traps), other than the assertion that it consumes roughly 15% of the total budget ($651,101.71 for year 1; their Appendix S3) or, at $20/hour (their standard), about 100 minutes ($33.50) per sampling date. This field labor allowance is greatly underestimated because travel to and from locations twice each sampling day to place and collect pan traps and their contents will be a daylong task when sites are remote or will require half a day for sites of intermediate access. Their allowance of 100 minutes would apply only to sites near the laboratory. An average estimate of 240 minutes for field labor ($80/sampling date) is more realistic and would add about $240,000 (about 37%) to the labor estimate and >20% to the total cost estimate.

Conclusion

We concur with LeBuhn et al. and others (e.g., Winfree et al. 2009) that surveillance monitoring of bee communities can provide the impetus for conservation action. However, to be useful to practitioners, surveillance must examine specific hypotheses (Nichols & Williams 2006) rather than addressing broad objectives such as testing for declines in numbers and species richness over 200 unreplicated sites around the globe. Indeed, as presented, the authors' protocol cannot identify locations, habitats, or species at risk; illuminate the causes of a significant bee decline; or prescribe a remedy (Nichols & Williams 2006). Thus, after 10 years of data collection and millions of dollars spent, we would be no closer to solutions than when we began. Instead, we would be reduced to pursuing remedial actions already recommended or practiced (i.e., habitat preservation and restoration, corridor construction, reduction of pesticide use).

More informative would be a series of surveillance studies to assess the impacts of specific anthropogenic challenges to bee populations (Winfree et al. 2009) in carefully chosen areas. For example, Cusser and Goodell's (2013) study of the response of bee species richness to floral diversity and distance from remnant habitat in restored prairie patches on reclaimed mine sites suggests practical applications. The shalelands of the western United States, currently undergoing widespread topographic disturbance, present a compelling opportunity for a planned surveillance study to measure the effect of rapid energy development on populations of bees in replicated disturbed and undisturbed sites. Such a study could suggest actions to ameliorate negative effects of energy extraction. Parallel surveillance of bee communities in carefully selected protected areas could provide comparable data for relatively pristine areas. It is only through such a judiciously chosen mix of representative monitoring studies that we will learn where bee populations actually are declining, identify the stresses associated with those declines, and develop approaches to reverse that trend.

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