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Comment

Evidence-based conservation: reply to Tepedino et al.

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Tepedino et al. (2015) identify potential errors in our claim that it is possible to develop a regional or global monitoring program that could detect modest declines in pollinator communities over a short period and at reasonable cost. Their position is largely based on the view that pollinator communities are already in decline and thus monitoring is an unnecessary waste of resources. We disagree. Because current evidence for widespread declines is lacking for most taxa, monitoring is an essential and sensible prerequisite for governments and NGOs commit resources and undertake future mitigation actions. We too are concerned that pollinator communities may be under threat, although the scale and extent of declines remain unquantified, and this was the aegis for our paper (LeBuhn et al. 2013).

We focused on evaluating the feasibility of assessing the status and trends in pollinator communities on regional or global scales. Our aim was to develop a tool which would provide the evidentiary basis to allow relevant stakeholders to make informed decisions and, where appropriate, commit to actions to support pollinators and their services. Therefore, we illustrated the sensitivity and feasibility of a monitoring program and not the details of its implementation.

Tepedino et al. cite as support for their view an opinion piece by Nichols and Williams (2006) in which the authors argue that monitoring is not useful. However, Nichols and Williams (2006) acknowledge the need for baseline data before appropriate causal hypotheses can be generated and that sufficient evidence is needed to precipitate organizational shifts for any global environmental problem, including the status of pollinator populations. We need not look further than the current debate on the causes of global climate change to observe the mix of conflicting responses to an incontrovertible evidence base. So, what evidence is sufficient to lead to concerted action? We do not purport to know the answer to this question. We know only that as scientists we strive to develop independent evidence bases, including measures of uncertainty, to help inform and guide decision makers in addressing societal concerns.

We agree with Tepedino et al. that any monitoring program should leverage the program and the data collected to have maximum benefit. In developing countries, resources should be invested to insure that collections enhance the in-country ability to identify and understand the ecology of the pollinators and the ability to design, analyze, and interpret such studies. Relevant covariates

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should be measured (e.g., extent of pesticide use, area of native vegetation, extent of agriculture) so that spatial variation in pollinator communities might be used to parse the causes of any observed trends. Furthermore, the purpose of the monitoring program, the role of pollinators in servicing agricultural crops and native vegetation, and identifying steps that could conserve pollinators should be explained as part of an outreach program to engage those who depend on pollinators for their livelihood. However, if resources are limited, then the program must focus on its primary aim (quantifying shifts in the bee community) in order not to impair its ability to detect change. If the program is unable to provide strong evidence that declines are actually occurring, then measuring potential drivers of change and community engagement is irrelevant and those resources are better committed elsewhere.

Tepedino et al. calculate that 1.3 million bees and other insects will be sampled during our monitoring program. We agree that the collections produced as a result of monitoring must be thoroughly used. However, there is no evidence in the literature that suggests a monitoring program involving pan traps would have long term impacts on pollinator populations or on nontarget arthropods. The only research addressing this issue that we could locate showed no effects of sampling on bee abundance or species richness when comparing sites that had never been sampled with sites that had been sampled every 2 weeks each summer for 4 consecutive years with pan traps and hand netting (Z. Gezon, personal communication). Given that we propose sampling only 1 year in 5, the impact of sampling would be even less. Furthermore, Tepedino et al.'s estimate of the number of bees we would collect pales in comparison with some other trapping programs, such as the 71–350 billion nontarget insects estimated to be killed within 40 nights in the United States by electric insect traps designed to reduce the incidence of mosquito bites (Nasci et al. 1983; Frick & Tallamy 1996). We welcome the call to reduce bycatch and to make use of the nontarget specimens collected.

Tepedino et al. criticize our estimates of interannual coefficients of variation (CV) in bee abundance and species richness. They are particularly concerned that the values of detrended interannual CVs we used for bees are lower than reported for other arthropod groups by Gibbs et al. (1998). However, our CVs should not be compared with Gibbs et al.'s (1998) because their CVs are largely for individual or small groups of species (S. Droege, personal communication). Our CVs are for the summed abundance of the entire sampled bee community. Although CVs are scale invariant, they are not invariant to changes in location. A numerical example illustrates this issue. Imagine a community of 10 species each with mean abundance of 5 and variance in abundance of 25. These 10 species would each have a CV of 1 or 100% if multiplied by 100 to express the CV as a percentage of the mean. Now for this hypothetical community of species, the sum of the abundances would be 50 and the variance in the summed abundance would be 250 (for independent random variables the variance of the sum equals the sum of the variances [Feller 1968]). However, for the community as a whole the CV in abundance would be $CV_{sum} = \sqrt{250/50 = 0.316}$ (or 31.6%). So, the CV for this community would be approximately one-third of the CVs of its individual members. If some species have correlations in abundance, then the CV will depend on the balance of these correlations with positive or negative correlations increasing or decreasing the CV, respectively. So, community level CVs should on average be lower that individual species CVs, and this is what led Tepedino et al. to erroneously conclude that the CVs we used were too low. However, it is this property of CVs that led us to choose the total abundance of the bee community as our metric rather than to use the abundance of individual species or of the 5 most abundant species. For bee species richness, there are no published values of detrended interannual CV, so Tepedino et al.'s complaint about our values for species richness are unfounded. Furthermore, we reported estimates of CVs based on 8 different sampling methods from 11 studies across 3 continents, all that were available. For all but visual counts, the CVs were similar in magnitude. Our search of the literature revealed no evidence that made us doubt the reasonableness of CVs we obtained for bee communities from all sampling methods.

Tepedino et al. also claim that the CVs we used for population trend are "improbably small," but they offer no evidence to support this claim. The CV for the process error (population trend) for total bee abundance and for species richness that we reported, 2.05% and 1.11%, respectively, was estimated from the pan trap data in the studies we reviewed. However, Tepedino et al. are correct on this point, but only because we failed to present the process error CVs (detrended interannual CVs) and nonprocess error CVs in the same manner. To make them consistent, we needed to multiply the process error CVs by 100, as we did for the nonprocess error CVs. The actual CVs should have been listed as 205% and 111%. Hence the CVs based on process and nonprocess error combined with the stochastically set initial abundance or species richness of the community determine the overall level of uncertainty in our simulation. Although we agree that more data from a wider set of geographical regions would be useful and advisable before establishing a monitoring program, both to insure that our current estimates of CVs are not under estimates and to test the effectiveness of pan traps in other habitats, we openly addressed these contingencies. In sum, we conclude that Tepedino et al.'s concerns about our CVs are without an evidentiary basis.

The preliminary data we used from pan traps suggested that a site in the temperate zone where bees are sampled with 30 pan traps for the field season would trap on average 375.1 bees/year. We used this value in our simulations to estimate the sample size required to have at least 80% power to detect declines in the abundance of bees. However, increasing the initial number of bees trapped per site per year leads to higher power and lower required samples sizes to detect community declines. Therefore, the values we reported may represent over estimates of the sample sizes required to detect declines. For the purpose of cost estimation, we used higher values of number of bees trapped per site per year because in a comprehensive monitoring program the inclusion of sample sites in regions with longer growing seasons might increase the number of bees trapped. We used 4 bees/pan trap/date and 26 sample dates/year to estimate costs because we thought it wise to err on the side of over estimating the program cost.

Finally, Tepedino et al. criticize our cost estimates for this monitoring program because we did not include the cost of the travel to the field sites. In establishing a network of long term monitoring sites, we envisioned the establishment of a multicollaborator network where each site is managed locally much like the deployment of national weather stations in the United States. One of the reasons we suggest that pan traps be used is that they do not require an expert on site to do the field collections. Clearly the costs would be higher if researchers were required to do the field collections. We believe that embedding bee sampling into already established sampling site networks (e.g., weather, agricultural research stations, national park systems) would be an effective way to establish national or international networks for monitoring bee decline.

Should our analysis of the feasibility of a monitoring program for bees stimulate governments or nongovernmental organizations to implement such a program (as is underway in the United Kingdom), we hope Tepedino et al. will join us and the community of scientists involved in pollinator ecology to insure that such a program is well designed and that the resulting collections are used efficiently. Our analysis has already initiated a conversation about how to accomplish this goal, and we thank Tepedino et al. for contributing to this discussion.

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