**Title**

Comment on Crossley *et al.* 2020: why the details matter in meta-analyses on insect declines

**Authors**

Ellen A. R. Welti[1*], Anthony Joern[2], Michael Kaspari[3]

**Author Affliations**

[1] Senckenberg Research Institute, Gelnhausen, Germany 63571

[2] Division of Biology, Kansas State University, Manhattan, KS 66506

[3] Geographical Ecology Group, Department of Biology, University of Oklahoma, Norman, OK 73019

[*]corresponding author; email: ellen.welti@senckenberg.de

**Response to:**

Crossley *et al.* 2020. No net insect abundance and diversity declines across US Long Term Ecological Research sites. *Nature Ecology & Evolution* (2020) doi:10.1038/s41559-020-1269-4.

**Abstract**

In an article recently published in Nature Ecology & Evolution (Crossley et al. 2020 "No net insect abundance and diversity declines across US Long Term Ecological Research sites"), sampling effort within Long-Term Ecological Research (LTER) datasets was assumed to be consistent across years. This is unlikely the case in most long-term ecological monitoring efforts. It is definitely not a correct assumption for the Konza Prairie grasshoppers, the dataset included in their analysis that we are most familiar with, as is documented in the online meta-data. As sampling at Konza increased over the duration of this time series, Crossley et al's assumption of invariant sampling effort led to a biased result of increased grasshopper abundances over time. This is likely a general problem with Crossley et al.'s analysis, given the complex history of many long-term datasets at LTER sites.

**Response**

Crossley et al. (2020)[1] conducted a meta-analysis to examine patterns of change in insect abundance across US Long-Term Ecological Research (LTER) sites, concluding "a lack of overall increase or decline". This is notable if true, given mixed conclusions in the literature regarding the nature and ubiquity of insect declines across regions and taxonomic groups[2–5]. These data, downloaded from US LTER sites, represent unique time series of arthropod abundances. While such long-term datasets can provide much needed insights, capturing both steady changes and responses to sudden unpredictable events, they are also rarely uniform in sampling protocols across their full duration as a result of the changing goals and abilities of a research site to collect data. Crossley et al.'s results rely upon a key, but flawed, assumption, that sampling was collected "in a consistent way over time within each dataset". Here we show this assumption incorrect, as is clearly documented in the meta-data (see CGR02 in http://lter.konza.ksu.edu/sites/default/files/MM.pdf), in one of their featured datasets — Konza Prairie (KNZ) grasshoppers — and that this error contributes to their key conclusion, a lack of evidence for net change in insect populations.

We refer to a dataset we know well[6–9], which documents grasshopper abundance by species, collected on 14 KNZ watersheds with the full dataset duration spanning 1982-present (up to 2015 included in Crossley et al. 2020). Crossley et al. analyze species within datasets separately (increasing the number of "Time trends" in their Table 1), but data from many of the LTER locations, including KNZ, are pooled across all sampling within an LTER (number of "Sites" in their Table 1). Importantly, the same number of watersheds (subsites) at KNZ are not sampled in all years, nor were the same number of samples collected within each watershed each year. The number of watersheds sampled per year varies from 6-14, and most notably, six bison grazed watersheds were added to KNZ sampling in 2002. Bison grazed watersheds support higher grasshopper densities, and more and different species composition[6,7]. When we analyzed these same data[8], we accounted for this change in sampling effort, and documented a 2% annual decline in grasshopper abundance over 20 years, with only one common species increasing (individual species analyses are provided in Appendix 1, Figs. S3-S5)[8]. Crossley et al, in contrast, report no such decline in grasshoppers, and instead report most grasshopper species increased in abundance from 1982-2015. Crossley et al. note this discrepancy with both our study[8] and another meta-analysis[3] and suggest it is "driven by falling numbers of just two once-dominant species… whereas many other formerly rare species have become more abundant and both evenness and species richness have increased". However, we believe the discrepancy arises from not accounting for variable sampling effort and KNZ's added sampling of more diverse grazed habitats midway in the time series.

Finally, Crossley et al. include several taxa (i.e. Tettigoniidae, Oecanthinae, and Gryllidae) in their analysis of the KNZ grasshopper dataset. These taxa were only included in the dataset starting in 2013. Thus the apparent abrupt "increases" in these taxa further bias Crossley et al.'s results.

We have not analyzed the other datasets included in Crossly et al. (2020). But given their mistakes with the KNZ data—driven by their key assumption of invariant sampling effort over the duration of LTER monitoring studies—we urge skepticism regarding their general conclusion of no net decline in insect abundances at US LTER sites in recent decades. Failure to take into account sampling effort in long-term datasets *at best* will increase measurement error and bias toward a null result (like Crossley et al's overall conclusion). At worst, as we've shown, when a site's sampling effort increases or decreases among years, it can generate even more erroneous conclusions regarding population change. Recently, a study reporting widespread collapse of rainforest insect populations at Luquillo, an LTER site, necessitated a similar correction[5] . We echo those authors, when they suggest that scientists can avoid such fixable errors by contacting in advance (and even including as authors) the field biologists collecting these data. We also recognize, sadly, that corrections such as ours are rarely as widely cited as the flawed original report[4,5]. Like the ecology they document, it is important to take into account that long-term monitoring efforts by institutions like LTERs are themselves complex and full of history.

**Author Contributions**

All authors discussed the work of Crossley et al. and jointly conceived the idea for the paper. E.A.R.W. wrote the first draft. A.J. and M.K. significantly contributed to revisions.

## Competing Interests

The authors declare no competing interests.

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