nature ecology & evolution

MATTERS ARISING

https://doi.org/10.1038/s41559-021-01424-0

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Studies of insect temporal trends must account for the complex sampling histories inherent to many long-term monitoring efforts

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ARISING FROM M. S. Crossley et al. *Nature Ecology & Evolution* https://doi.org/10.1038/s41559-020-1269-4 (2020).

Crossley et al.[1] examine patterns of change in insect abundance and diversity 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 insect taxonomic groups[2–6]. The data analysed, downloaded from and collected by US LTER sites, represent unique time series of arthropod abundances. These long-term datasets often provide critical insights, capturing both steady changes and responses to sudden unpredictable events. However, a number of the included datasets are not suitable for estimating long-term observational trends because they come from experiments or have methodological inconsistencies. Additionally, long-term ecological datasets are rarely uniform in sampling effort across their full duration as a result of the changing goals and abilities of a research site to collect data[7]. We suggest that Crossley et al.'s results rely on a key, but flawed, assumption that sampling was collected "in a consistent way over time within each dataset". We document problems with data use prior to statistical analyses from eight LTER sites due to datasets not being suitable for long-term trend estimation and not accounting for sampling variation, using the Konza Prairie (KNZ) grasshopper dataset (CGR022) as an example.

Unsuitable datasets to estimate long-term observational trends

Several of the LTER datasets included in Crossley et al. document experiments that either have confounding treatment effects or are too variable in sampling methods to allow for comparison of samples across time. Additionally, in one case, lepidopteran outbreak dynamics with long intervals (10–13 years) at Hubbard Brook limit the power to detect meaningful trends without extremely long-term data[8]. Datasets from Cedar Creek include arthropods collected in plots with nitrogen addition, herbivore exclosures and manipulated plant diversity. All three of the datasets from Harvard Forest included in Crossley at al.'s analysis have large methodological inconsistencies over time and one dataset documents ants collected in a canopy manipulation experiment, including one treatment where trees were girdled to simulate hemlock woolly adelgid (*Adelges tsugae*) infestation of the hemlock trees years prior to the arrival of the invasive insect to the area. One dataset from North Temperate Lakes documents the responses of two crayfish species in a lake where one species was being experimentally removed. With a few exceptions for partial components of these datasets (for example, control plots in the arce153 Cedar Creek dataset), these data are inappropriate for estimation of long-term observational species trends.

Not accounting for sampling variation and Konza grasshoppers as a case in point

The KNZ CGR022 dataset documents grasshopper species abundances on 15 KNZ watersheds and spans 1982 to present (up to 2015 included in Crossley et al.). Crossley et al. analyse time series of individual species from each dataset (the number of 'time trends' in their Table 1). However, regardless of variant sampling effort, they regularly sum all individuals within LTER datasets to yield a single value of abundance for a given species and year. This is the case for KNZ grasshoppers and most other included datasets (number of 'sites' in their Table 1). Importantly, sampling effort at KNZ and other LTER sites was not constant. At KNZ, variation occurred in the number of samples per watershed and the number of watersheds in which grasshoppers were collected per year (Fig. 1). Most notably, six bison-grazed watersheds were added to KNZ sampling in 2002. Changes in sample numbers over time are documented in the online metadata (http://lter.konza.ksu.edu/content/cgr02-sweep-sampling-grasshoppers-konza-prairie-lter-watersheds).

Not accounting for sampling effort and data structure causes errors in trend estimates (see also Supplementary Information and Supplementary Fig. 1). At KNZ, bison-grazed watersheds support higher grasshopper abundances and species richness[9,10]. In a recent analysis using the CGR022 dataset, to account for this change in sampling effort, only data collected in the same years from watersheds were combined (for example, by splitting samples from grazed watersheds into a separate time series) and abundances within each watershed and year were divided by the number of samples. Analysis of the data structured in this way showed a >2% annual decline in grasshopper abundance, with only one common species increasing[11]. Crossley et al., in contrast, report that most grasshopper species increased in abundance from 1982 to 2015. Crossley et al.

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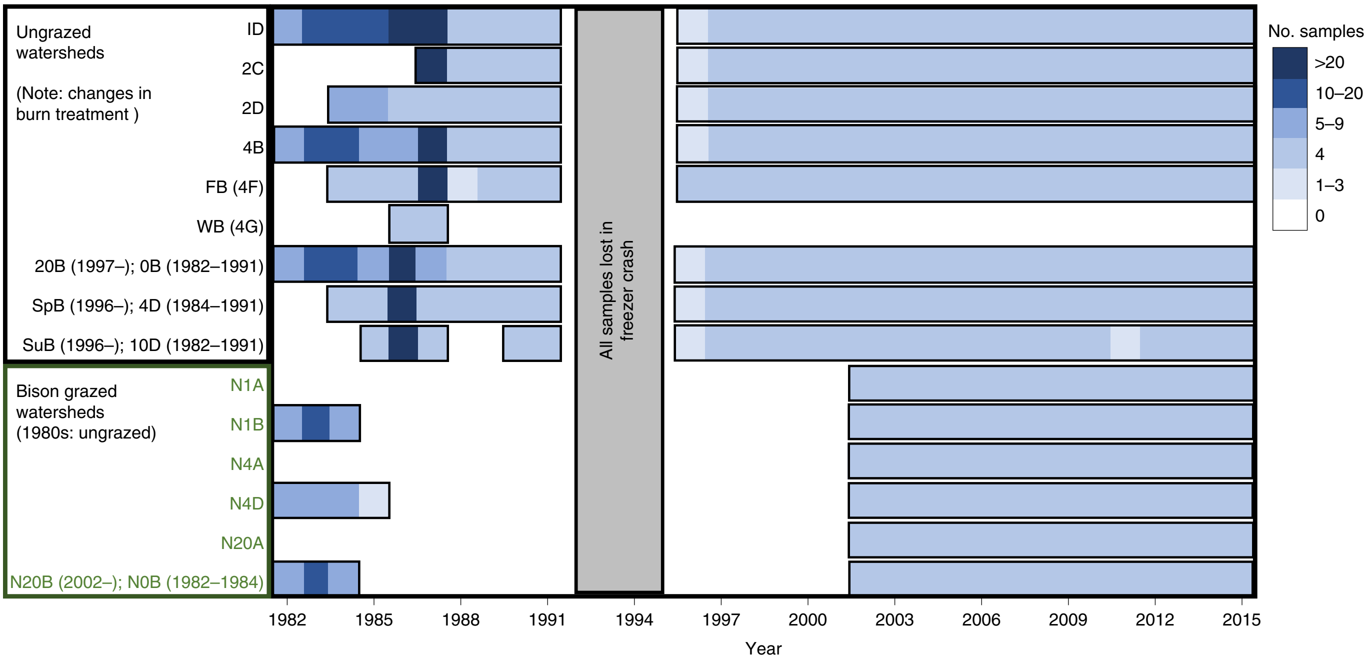

Fig. 1 | The complex history of sampling of the KNZ grasshopper dataset. The KNZ grasshopper dataset (CGR022) exhibits high variance both in number of watersheds sampled per year (number of bars per year) and number of samples collected within each watershed each year (depicted in colour). Other complexities include the tragic loss of four years (1992–1995) of sampling due to a freezer crash, changes in sampling month, changes in watershed burn frequencies and the reintroduction of bison in the 1990s to six of the later-sampled watersheds.

note the discrepancy with both this study[11] and another[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 because Crossley et al. did not account for variable sampling effort, including KNZ's incorporation of additional, more diverse grazed habitats midway in the time series. Similar errors, where data structure was not accounted for, are evident in 17 of the 19 datasets that we examined and were included in Crossley et al.'s results.

Conclusion

We have thus far been able to confirm issues with data from 8 of the 13 LTER sites (comprising 60% of Table 1's 'time trends') included in Crossley et al. We note that this is not a comprehensive assessment, as we have included errors only from datasets for which either we ourselves are the principal investigators or we have been able to confirm with the corresponding LTER principal investigators and information managers. The eight sites are: Baltimore, Cedar Creek, Central Arizona–Phoenix, Harvard Forest, Hubbard Brook, Konza Prairie, North Temperate Lakes and Sevilleta. We provide details on dataset unsuitability, mistakes in not accounting for sampling effort and several coding errors in the Supplementary Information.

Given these mistakes, we urge scepticism regarding Crossley et al.'s general conclusion of no net decline in insect abundances at US LTER sites in recent decades. Although their goal is laudable, both the use of unsuitable datasets and not taking sampling effort into account generate erroneous estimates of population change. Recently, a study reporting widespread collapse of rainforest insect populations at the LTER Luquillo site necessitated a similar correction[5]. We echo those authors, when they suggest that scientists can avoid errors by reading corresponding metadata. Contacting the data providers/field biologists in advance (or even including them as authors) is an additional good practice that ensures appropriate use of the data. Like the ecology they document, it is important to take into account that long-term monitoring efforts by LTERs and similar institutions are themselves complex and full of history.

Reporting Summary. Further information on research design is available in the Nature Research Reporting Summary linked to this article.

Data availability

KNZ grasshopper abundance data are available from the Long-Term Ecological Research Data Portal (https://doi.org/10.6073/pasta/7b2259dcb0e499447e0e11dfb562dc2f). Citations for the additionally described LTER datasets are provided in the Supplementary Information.

Received: 19 August 2020; Accepted: 23 February 2021;
Published online: 5 April 2021

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Acknowledgements
S. LaDeau, S. Earl, S. Barrott, E. Borer and S. Pennings aided in identifying errors in Crossley et al.'s online data. K. Roeder provided comments on an early draft of this manuscript. J. Taylor aided in identifying changes in Konza watershed names. We thank all LTER information managers and principal investigators who help keep online metadata updated. We thank P. Montz, J. Haarstad, A. Kuhl, M. Ayres, R. Holmes and the numerous others who did the hard work to generate these long-term datasets. NSF DEB-1556280 to M.K. and Konza Prairie LTER NSF DEB-1440484 supported this work.

Author contributions
E.A.R.W., S.R., A.J. and M.K. conceived the idea for the paper. E.A.R.W. wrote the first draft. A.M.E., D.C.L., S.R., N.R. and E.H.S. identified further errors in the Crossley et al. online data. All authors significantly contributed to revisions.

Competing interests
The authors declare no competing interests.

Additional information
Supplementary information The online version contains supplementary material available at https://doi.org/10.1038/s41559-021-01424-0.

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Peer review information *Nature Ecology & Evolution* thanks Nick Isaac, Manu Saunders and James Bell for their contribution to the peer review of this work.

nature research

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Last updated by author(s): Jan 28, 2021

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