Discussion

*Summary of results, implications, and comparison to wider literature*

The shiny app presented represents a major contribution towards the improvement of our understanding of insect population trends, something which research to date has strived to achieve, but failed to clearly understand. We show how the app is designed to use data from effectively a living review of meta-analyses on insect population trends, where new studies can be added and the app can immediately update upon new data existing in the living review database. Using this data within the app, the user can interactively run their own custom models based on their hypotheses and visualise their results.

The app is useful for making decisions specific to the user’s interests. Insect population trends are complex, showing variability geographically, taxonomically, and temporally, which makes it unlikely that literature will exist for the specific combination of variables the user is interested in. However, the shiny app can partially overcome this issue by giving the user access to a vast collection of data and the tools to analyse it in such a way that they can get an indication of how insect populations act in, and are influenced by particular circumstances. This may also indicate potential findings that would be interesting to investigate further, perhaps in a new meta-analysis, the results of which could eventually be incorporated into the app.

Comparing the app presented here to previously created apps, the biggest similarities occur between the shiny app and a tool called dynamic meta-analyses, created alongside the Metadataset website (Shackelford *et al.*, 2021). At this stage, dynamic meta-analyses provides the users with more filters and options on ways to analyse the data. Dynamic meta-analyses allows the user to perform sub-group analyses, as in the shiny app where results are based on a filtered subset of the data. The dynamic meta-analyses app also enables meta-regression, where different subsets are analysed whilst accounting for effects of other variables. The stand-out feature of the shiny app presented here is the ability of the user to upload their own data directly from within the app. This will allow the app to continue to grow and become increasingly useful in future, without the need for someone to be responsible for identifying new data sources and adding them to the database.

This app is a tool which allows researchers to take full advantage of the insect data we have, and will aid scientists in disentangling the complex patterns and drivers of population trends, especially as more data become available.

*Limitations/future directions*

In its present state, the app has all the necessary framework to prove the value and richness that these kind of tools can provide. Nevertheless, there are a number of things that could be adjusted or added in to further increase its usefulness.

Firstly, the custom model that can be run by the user is currently based upon a choice od biodiversity metric category, included due to researchers concluding different results when measuring biodiversity with different metrics. GIVE E.G.. We plan to expand the range of variables over which a user has choice, which can be easily added assuming sufficient data is available. For example, including a choice of location of where the data was collected would be ideal for investigating geographic variation in results. This is difficult with the current dataset due to the majority of datapoints not including location data, as well as inconsistent location descriptions; some studies report multiple continents, others individual countries.

The app currently runs robust models, which deviates from other meta-analysis studies where using the metafor package is popular. The reason for this is due to the studies in this dataset not reporting necessary effect sizes and variance statistics needed for this package. However, if new meta-analysis studies do sufficiently report these statistics, it may make sense to switch to this approach, especially seeing as robust models will take longer to run as more data is added. Additionally, metafor will allow the option of meta-regression — as used by Shackelford *et al.* (2021) — which is more powerful than sub-group analysis due to including all the data.

Clearly, the app is limited by the quantity and quality of available data. Although many have highlighted deficiencies in the reporting of statistics necessary to complete meta-analyses, there are still improvements that need to be met. As we progress into new approaches such as meta-meta-analyses — data of which is used in this app — these principles must be upheld. For the reason that meta-analysis studies did not report sufficient statistics, the app is designed to run robust models, rather than metafor models. This does not mean robust models are not useful, but we cannot obtain results in the same style as classical meta-analyses, neither compare the two approaches.

For maximum potential to be achieved, the app relies upon a harmonised process being in place. This includes following a standardised protocol and data entry sheet for all future meta-analyses. With these in place, the data collected from different studies becomes more comparable, and requires less data re-structuring before incorporation into the app. A protocol for the use of the app will also need to be assembled to avoid the issues of cherry picking, where users run multiple models, but only report findings which support their hypotheses, ignoring those that do not.

~~Assess whether met aim.~~

~~Main findings~~

* ~~App uses data from a living review and is interactive. Updated as soon as new studies are added.~~

~~Usefulness~~

* ~~Researchers can’t give evidence for all combinations of variables – there are so many and they are so variable geographically, taxonomically, temporally, metrically etc. My shiny app can help. Make informed decisions specific to your question~~.
* ~~Starting point for more detailed analysis?~~

~~Compare to other shiny apps e.g. Shackleford~~

* ~~Compare to dynamic meta-analysis – they have more filters etc. which I would envision mine to have in future. But mine does have the USP of users being able to upload data directly, which is not true of metadataset. Think the makers of the app would have to continue to be responsible for this.~~

*~~Limitations/future directions~~*

~~There are lots of things that could be tweaked, adjusted, added in pretty easily. Basic app framework is there as a proof of concept.~~

~~More than just biodiversity metric category~~

~~Incorporate species attributes / environmental variables into it.~~

~~Further down the line, may not have to use robust models. If new MAs report effect sizes and variance (unlike the papers that Christina used), we may be able to use metafor. BUT this relies on having a harmonized process where everyone follows a standardised protocol and data entry sheet. Move away from running robust model, and run metafor models instead.~~

~~Protocols for how app should be se to avoid issues with cherry picking or data dredging.~~

~~Still limited by quantity and quality of available data. Data reporting must still be improved. Publication bias etc. See MA essay.~~

~~Robust models will take longer to run as more data added – switch to metafor models?~~

Shackelford, G. E., Martin, P. A., Hood, A. S., Christie, A. P., Kulinskaya, E. and Sutherland, W. J. (2021) Dynamic meta-analysis: a method of using global evidence for local decision making. *BMC biology.* 19 (1), 1-13.