Comment on Hallmann

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Hallmann et al. (2017) concludes that there is a dramatic decline in insect biomass. Considering the fact that this result was found using data gathered in nature conservation sites, makes this finding even more alarming. The authors reported a decline of "more than 75 percent" over 27 years. The majority of contributing effects to this development remains unknown.

We want to point out critical aspects of the publication, check for their relevance in the statistical analysis, and discuss the paper within the context of our approach. The following bullet points give an overview over some aspects of the analysis we identified as problematic:

- Years 1989 and 2014 are over-represented
- Few locations were re-sampled
- Only one trap per location
- The exposure time varies greatly among years
- Unknown site selection procedure
- Lack of control group

Considering these issues and taking into account the impact the publication had, and still has, we want to asses the robustness of its results, mainly the decline of insect biomass.

A possible bias in the site selection process and the low number of re-sampled sites, give rise to suspect regression to the mean influencing the findings of Hallmann et al. (2017). Barnett, Pols, and Dobson (2004) describe regression to the mean (RTM) as a statistical phenomenon were the normal variation of repeated measurements appears to be a real change, simply because with every additional measurement the values are closer to the mean. RTM can appear as a selection phenomenon, when there is no control group and no random sampling of measurements sites or individuals (Blomqvist 1987; Kelly et al. 2005). Within ecological research, however, implementing a control group can be impossible, for example when investigating temporal changes as it is the case here. We argue, that during site selection, locations with favorable attributes were chosen to maximize the efficiency of the traps, leading to extreme values in the initial measurements. Over the duration of the sampling process the 'quality' of the sites that were yet to be sampled decreased. Since we could not test the results on RTM by redefining the sampling design, we tried to rule out the effect, by only including the first year of sampling per plot in our analysis.

We ran the basic model with a subset of the original data, using the same presets as Hallmann et al. (2017) (i.e. number of iterations, chains, and amount of thinning). The output showed that even with less data, the model diagnostics where similar to the ones of the complete data set.

Our result did not differ substantially from Hallmann et al. (2017). The hypothesis of a intensified insect biomass decline due to regression to the mean could not be verified. We report a decline of flying insect biomass of 81 % within 27 years during times with the highest biomass. This is a discrepancy of 0.4 % from the original result (~ 81.4 % decline). The original results seem to be robust from this point of view. There was, however, another interesting aspect about the original analysis

The exposure intervals of the traps tended to increase over time. This could be problematic, since the amount of biomass per trap did not decline significantly over the period of the study. The strong decrease only occurred when calculating daily biomass values. To deal with the varying exposure times, the insect biomass model was build to account for the temporal differences by calculating the daily latent but unobserved biomass. This approach should be valid in the present case, but could hypothetically, lead to a bias, when an effect disrupts the proportionality of biomass and days of exposure by a decline of daily catches.

Ultimately, we found the statistical methods used in the analysis to be reasonable, especially for the given data set, as most of the issues we pointed out were introduced by sampling.

Nevertheless, RTM remains to be a critical aspect in ecological modeling. The low awareness and coverage of RTM in environmental analyses became obvious to us during this course. A quick comparison between search results of RTM effects in ecology revealed this. Compared with epidemiology (over 100 articles, cited > 1000 times), ecology was greatly underrepresented in research addressing RTM (only 3 articles, cited < 200 times). Therefore, we want to point out the need to further include the phenomenon of RTM in ecological data analysis. Fortunately, in the current issue of 'Nature' magazine, de Haas shares his story of the retraction of an article caused by an overlooked RTM effect (Haas 2021), which could raise awareness of the topic in the natural sciences community.

References

Barnett, Adrian G, Jolieke C van der Pols, and Annette J Dobson. 2004. "Regression to the mean: what it is and how to deal with it." *International Journal of Epidemiology* 34 (1): 215–20. https://doi.org/10.1093/ije/dyh299.

Blomqvist, Nils. 1987. "On the Bias Caused by Regression Toward the Mean in Studying the Relation Between Change and Initial Value." *Journal of Clinical Periodontology* 14 (1): 34–37. https://doi.org/10.1111/j.1600-051X.1987.tb01510.x.

Haas, Ben de. 2021. "What My Retraction Taught Me." *Nature* 589 (7842): 331. https://doi.org/10.1038/d41586-021-00073-4.

Hallmann, Caspar A., Martin Sorg, Eelke Jongejans, Henk Siepel, Nick Hofland, Heinz Schwan, Werner Stenmans, et al. 2017. "More Than 75 Percent Decline over 27 Years in Total Flying Insect Biomass in Protected Areas." *PLOS ONE* 12 (10): 1–21. https://doi.org/10.1371/journal.pone.0185809.

Kelly, Colleen, Trevor D. Price, Associate Editor: Stuart A. West, and Editor: Michael C. Whitlock. 2005. "Correcting for Regression to the Mean in Behavior and Ecology." *The American Naturalist* 166 (6): 700–707. http://www.jstor.org/stable/10.1086/497402.