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Urban beekeeping and sustainability

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Abstract

This paper discusses weaknesses of an article addressing the sustainability of urban beekeeping in Switzerland. I show that some absolute figures cannot be reproduced using the supplementary material and that simulations do not respect the internal constraints of the model. I also question the conceptual framework of the study and conclude that the results of the study do not support the authors' conclusions.

Using administrative data, Casanelles-Abella & Moretti (CAM) address the question of sustainability of urban beekeeping(Casanelles-Abella & Moretti, 2022). They show that the number of hives has significantly increased in 14 Swiss cities between 2012 and 2018. Based on a modelling approach, they argue that the observed honeybee densities are not sustainable and may be harmful to wild bee species.

The paper provides interesting and useful figures regarding the development of urban beekeeping in Switzerland. In supplementary information, it provides datasets and an R-script which allows the reader to understand and reproduce the modelling process and its results. This material elicits several questions which I have discussed with the Managing Editor of npj Urban Sustainability between 17 February 2022 and 29 June. I pointed out several errors and questioned in depth the conceptual framework of the study. I asked for a right of reply which was not accepted. Only one error was corrected. I addressed the following issues:

Some absolute figures cannot be reproduced using the R-script and the supplementary material. According to the first version of January 2022, the total number of hives had increased by a factor 3, from 3139 to 9370 (corresponding to a density of 10.14 hives per km2), between 2012 and 2018. According to supplementary Table 1 which could be reproduced using the R-script, the total number of hives reaches 6370 and corresponds to a density of 8.1 hives per km2. This error was communicated to the editor on 17 February and was finally corrected on June 9. The authors reported it as a "typo", an explanation which is not convincing, since it should not affect density. This error was propagated in all subsequent communication, the authors having alerted the media in a special press release. I also reported that the supplementary Table 2 could not be reproduced using the provided R-script. In their Erratum, the authors declare that the corresponding lines of the script are « deprecated ». No correction has been provided.

Violations of the model constraints. In their modelling approach, the authors consider a variety of carrying capacities (CC) expressed as the "maximum number of hives that can be sustained in a cell covered 100% by UGS" (for Urban Green Space, a measure of the amount of space covered by green areas). The authors apply it on a grid of 1km^2 cells. A cell with 100% UGS is therefore completely green and does not contain any urbanistic elements. They evaluate CC in a range from 0.5 to 75 hives/km^2. They also consider increasing the numbers of UGS per cell in the range from 0 to 100%. Finally, they compute the number of UGS that would be required for all combinations of CC and increases in UGS. They then establish a diagnose of sustainability for each cell in each configuration.

I see the following difficulties with the modelling approach: at CC < 1 hive/km^2, the area necessary to support a single hive is larger than 1 km^2. For instance, for CC= 0.5 hive/km^2, two km^2 (or two cells) covered with 100% UGS would be necessary to support a single honeybee colony. The modelling approach does not properly handle this critical case. On the contrary, it evaluates every single cell separately, which means that for a CC of 0.5 each cell should be covered with 200% UGS, or two layers of UGS in order to support one honeybee colony, which is an impossible situation since the maximum for each 1km^2 cell should not exceed 100%.

This problem affects the results of their Figure 2 (2a, 2b, 2c & 2d) in the range]0,1[. On these four graphs, which display the percentage of cells with a negative balance between available and required resources, the baseline of the curves (with 100% of cells presenting a negative balance) corresponds precisely to a carrying capacity of 0. For CC=0, the R-script is confronted to a division by 0. It returns « Inf » (= infinite) for required resources and « -Inf » for balance between available and required resources. In addition, CAM also considered increasing the resources per cell in the range 0 to 100%, an increase of 100% corresponding to a doubling of the initial resources. In all cases in which the initial resources (measured in UGS) exceed 50% of the cell, an increase by 100% (i.e. doubling the green surface) also exceeds 100%.

In their erratum CAM admit that their modelling is inaccurate in the range [0,1[, but do not seem to fully appreciate its consequences. This range is not only critical in their model, but is also of great ecological relevance, since it is precisely the range of densities reported for unmanaged honeybee populations in forest environments (Seeley, 2007). No correction have been proposed for any of these modelling issues.

Finally, while most wild and solitary bee species collect their resources in a range of 0.3 km around their nest, honeybees harvest most of their nectar and pollen in a range of 1-3 km around the hive, i.e. within areas of approximately 3-30 km2. A cell grid of 1 square km is therefore clearly inappropriate to model the sustainability of hive densities. In addition, several cells are in agricultural or forest areas and do not justify the designation of "urban".

Is UGS a useful concept? I see several weaknesses with this concept. Firstly, it does not specifically apply to urban environments, since cells covered with any value of UGS in the range [0-100%] can be found in both urban and rural environments. Wouldn't it be more meaningful to consider "green spaces" irrespective of "urban" or "non-urban" environments? Secondly, this unit of measure does not convey any information about actual resources for bees, since resources differ widely between a lawn mowed every week and a green area covered with flowering plants and cut only once or twice a year. Thirdly, pollen and nectar resources are distributed in three dimensions, with trees being of particular significance. In conclusion, UGS is a very poor proxy for estimating bee resources, since it is not specific to urban environments and provides a two-dimensional measure of resources which are multi-dimensional.

Carrying capacity. The authors describe the carrying capacity as "the maximum number of honeybee hives that can be sustain[ed?] in 1 km2 of UGS". They then consider varying CC and compute the balance between available and required UGS for each CC. The authors do not seem to realize that CC is not an independent parameter which cannot be handled without taking its dependencies into account. CC depends both on the resources of the environment and on the species requirements. In their simulations, the authors consider fixed amounts of resources (e.g. 100% of UGS). Varying CC for a given amount of resources implies that the species requirements vary correspondingly. In other terms, the authors simulate bee species with different needs in resources, i.e. organisms that a naturalist would probably consider to be different species.

In a second step, the authors consider increasing the available resources measured in UGS in the range 0-100%. This is compatible with what ecologists would consider as a simulation of varying CC without affecting the requirements of the organism. Unfortunately, as shown above, CAM's simulations do not respect the constraints of their model.

An arbitrary threshold : according to CAM, the sustainability threshold is around 7.5 hives/km^2, a value close to the 8.1 corrected colony density calculated in the CAM study for the year 2018. This threshold is arbitrary and has not been established on solid scientifical grounds. It is based on speculative computations drawn from an "opinion paper" (Stevenson et al., 2020), which itself refers to two other articles (Alton & Ratnieks, 2013)(Alton & Ratnieks, 2016)) published in wide audience journals without scientific refereeing board. Alton & Ratnieks (2016) estimated the area requirement of lavender per colony to be 0.83 ha by observing an average of 0.6 bees present per m^2 of flowers which gives us an idea of the foraging intensity but no information about the area needed to cover the food requirements for one colony. This figure is therefore not suitable for defining a carrying capacity. Moreover, cultivated lavender does not produce pollen and honeybees cannot thrive in lavender monocultures.

In conclusion, I show that some results cannot be reproduced, that some critical constraints of the model are not respected, that the conceptual basis of the study is weak and questionable and that the strong conclusions of the authors are therefore not supported by the results of their study.

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