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COMMENTARY

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Response to Zöller et al.'s critique on "Potential short-term earthquake forecasting by farm-animal monitoring"

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Abstract

Zöller et al. (Ethology, 2020) criticize our original publication (Wikelski et al., Ethology, 126(9), 2020, 931) for obvious reasons: we only observed the behavior of one group of farm animals before, during and after one earthquake series in one area of the world. It is clear that no earthquake predictions are possible, and should not be attempted, from this data set. However, what we show is that there is important information within this animal collective pertaining to potential future local forecasting of earthquakes when combined with traditional data sources. We maintain that combining Zöller et al.'s (2020) modeling tools with the adequate use of our data can stimulate novel ways of earthquake forecasting. Future studies should combine both approaches.

KEYWORDS
collective behavior, disaster, earthquake, emergent sensing, forecasting

Zöller et al. (2020) somewhat misinterpret the goal of our paper (Wikelski et al., 2020), which neither tries to perform earthquake predictions nor does it claim that the current quality of measurements is sufficient to perform earthquake predictions.

The reason for the poor prediction quality found by Zöller et al. can be manifold. Firstly, as stated above, the data are insufficient for a prediction exercise. The predictor variable, that is, the animal anomalies, contains a vast majority of events that are not earthquake related. This includes high activity during milking times, disturbances due to other farming activities, and the impact of the regional/local weather and its immediate manifestations. There is also obvious room for improvement in terms of the number of farms and the selection of animal species. Moreover, also the use of the outcome variable, that is, the series of PGA anomalies, requires further attention. Neither do we have precise information on the three-dimensional Earth structure in the source region, nor did we separate mainshocks from aftershocks, such that our response variable is a first-order proxy for the activity we want to measure. Expectedly, noise in predictor and response variable leads to a relatively high number of false-positive and false-negative predictions. However, many of the deficiencies can be removed, or at least mitigated, in targeted future studies using a more elaborate experimental set-up. In this sense, we are optimistic that the early response of animals may be an informative predictor in a larger set of potential predictors and controls.

In the present study, however, our goal was to investigate whether signs for anticipatory behavior can be detected despite the aforementioned deficiencies. As prediction is not the goal, the choice of the hyperparameters, that is, thresholds of two standard deviations and a 20-hr window, is not optimized for prediction, but for the purpose of identifying a potential relationship between anticipation time and distance. Using these parameter values for prediction, as done by Zöller et al., is therefore suboptimal at best, or missing the point, to be precise. In general, not only the hyperparameters but also the design of the experiment and the model needs to be reconsidered for a prediction exercise. The Molchan diagrams in Zöller et al. show that none of the considered time windows leads to a satisfying prediction performance. However, this may be a result of incomplete hyperparameter tuning and suboptimal model design by Zöller et al. for their prediction exercise. For instance, cross-validation, adjusted for the time series context, would be a possible tool for necessary hyperparameter tuning in the prediction context.

Besides the predictive power of the animal anomalies, Zöller et al. discuss the effect of space-time clustering of earthquakes on the relation between anticipation time and hypocentral distance. Via randomization of the animal anomalies, they demonstrate the low significance of the relationship found in our analysis. We agree with this result, which we already discuss in the paper and in detail in the significance patterns in the supplementary materials (Wikelski et al., 2020). As we cannot control other external factors affecting animal activity with the data at hand, a low significance of the relationship is not surprising. Zöller et al. further argue that the results may be driven by space-time clustering, which was not considered in our analysis. This is a valid point which should be considered in further studies. We expect that considering the space-time clustering will increase the significance of the relationship if there is indeed a negative relationship. As the distance—anticipation time relation does not hold for aftershocks, given a slow diffusion-like process, we regard aftershocks as "noise" in our analysis. Therefore, removing these PGA anomalies may in fact help to better determine the negative relationship, which is in contrast to the argument of Zöller et al.

We acknowledge the argument of Zöller et al. that Molchan diagrams, that is, ROC-type curves for the earthquake context, are appropriate to evaluate the performance of an earthquake prediction scheme. However, as earthquake prediction is beyond the scope of our paper, we do not agree that the tools they use make the analysis more complete; instead, they in fact miss the philosophy of the paper. Once data become available that are suitable for prediction in future work, then the suggested tools will be helpful and appropriate. We agree with Zöller et al. that space-time clustering should be considered in future work, and we are optimistic that this will help to improve the significance of the results. We suggest that joint studies by earthquake researchers and animal behavior researchers, using the biological methods we outlined in our paper combined with the sensory and analytical tools outline by Zöller et al., could be a very productive way to further improve our understanding of whether and how collective animal behavior might help in forecasting earthquakes.

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