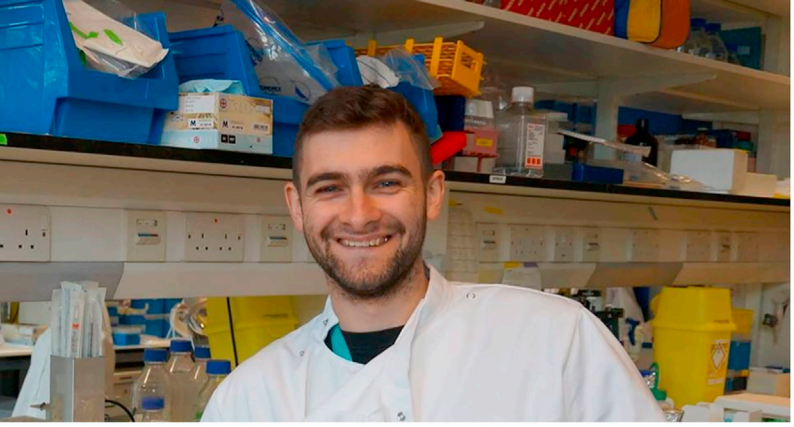

Backstory

Monitoring water quality: A citizen science success story

Benjamin Schäfer,[1,2] Catherine M. Heppell,[3] Hefin Rhys,[4] and Christian Beck[1,5]

Chalk streams, named after the chalk rock on which they flow, are iconic rivers valued for their clear waters, ecological richness and heritage status. They are globally rare ecosystems with a majority (224) located in England, United Kingdom (WWF, 2014). However, these rivers are under increasing pressure from urbanization and agricultural activity, threatening the water quality and ecology. Hence, within this collaboration and as described in the *iScience* article published recently (Schäfer et al., 2021), we want to monitor water quality, generally obtain a better quantitative understanding of the driving forces controlling different water quality determinands, and eventually contribute to improving water quality in the river. In this work we focused on the River Chess in the Chilterns 'Area of Outstanding Natural Beauty' located in the South-East of England. In this backstory we discuss the impetus of this research project, how the project was interdisciplinary, and how we hope this work can continue in the future.

BEGINNINGS

What is the river Chess and why is it special?

The River Chess is a chalk stream valued by its local community for its amenity value (culture, recreation, and aesthetics) and wildlife. However, it is also under pressure from human activities. The River fails to meet 'good ecological status' as determined by the EU Water Framework Directive (2000/60/EC) because of a combination of nutrient enrichment, low flows and poor health of its fish populations. To monitor and help improve the river's water quality and ecological status, several actors have partnered together (Queen Mary University of London (QMUL), the River Chess Association (RCA), the Chilterns Chalk Streams Project (CCSP) and Thames Water) to start 'ChessWatch'. The aim of which is to raise awareness of the current pressures on this chalk stream resource and to monitor the river quality to provide a baseline dataset owned by the public: https://www.qmul.ac.uk/chesswatch/.

The interdisciplinary team: (top left) Hefin Rhys, Citizen Scientist, (bottom left) Christian Beck, Applied Mathematics, (bottom middle) Benjamin Schäfer, Physics/Applied Mathematics, and (right) Catherine M. Heppell, Geography.

As part of the ChessWatch program, monitoring, and maintenance of four water quality sensors is taken care of by Citizen Scientists, adding another social dimension beyond the academic interdisciplinarity. Working on an ecological project where the local public and stakeholders are also involved increases the science-society engagement and transfer of knowledge. A ChessWatch Storymap has been created to help with knowledge transfer activities and is updated in realtime: https://storymaps.arcgis.com/collections/49dc7c8778214b66a086abc982339ae7.

How is this interdisciplinary and who is involved?

Although monitoring and collecting water quality data requires experimental and geographical expertise, evaluation of the recorded data naturally introduces further disciplines. In this case it started with Kate Heppell, Professor of Geography at QMUL, who was one of the key initiators of ChessWatch. Hefin Rhys, a data scientist who lives local to the River Chess, joined in as a Citizen Scientist both to analyze and clean the data, but also to develop an interactive web interface to visualize the data and make it available to the wider public: https://rhysh.shinyapps.io/ChessWatch/

Finally, Christian Beck, Professor of Applied Mathematics at QMUL and Fellow of the Alan Turing Institute, and Benjamin Schäfer, currently Associate professor in Physics at Norwegian University of Life Sciences (NMBU) in Norway joined for further statistical and data-driven analysis. With such a diverse team, interesting results soon followed.

NEW DATA, NEW METHODS, NEW RESULTS

This was an exciting project for everyone involved. Schäfer and Beck were especially delighted to have the opportunity to apply their mathematical methods to a completely new application. Jointly, they had already worked on so-called "superstatistical analysis" and applied these to data originating in air pollution measurements, power grid fluctuations and airplane delays. However, the water quality measurements posed some interesting challenges. For example, the time series display a very strong cyclic behavior and oscillations. Kate Heppell could easily provide context for this: Rivers, and in particular their biological components, follow clear circadian cycles, oscillating every day, with additional seasonal effects, driven by temperature and rainfall, varying during winter and summer.

The importance of novel methods of data analysis for environmental problems cannot be overestimated. Working in an interdisciplinary way opens up new avenues for solutions, aiming at a cleaner and sustainable local environment, and the ChessWatch project helped to widen public awareness.

Once these clear trends had been removed from the data, the team observed strong, non-standard fluctuations, which were well described by "superstatistics", i.e., the observed data was best described as a superposition of more than one statistic. Think of two different processes happening after one another, but you only receive the aggregated data of both processes. The goal is now to disentangle the aggregated data into its original parts. From a mathematical point this was very exciting as the data revealed some new effects, not described in this form in other datasets.

Even more exciting are implications for the water quality itself. The sensors used in the project record data both upstream and downstream of a sewage treatment site, and a key question was whether and how it influences the water quality. Although further work is still ongoing, it became clear that the mathematical models used here, already pointed to human cycles influencing aspects of the water quality. The importance of novel methods of data analysis for environmental problems cannot be overestimated. Working in an interdisciplinary way opens up new avenues for solutions, aiming at a cleaner and sustainable local environment, and the ChessWatch project helped to widen public awareness.

CHALLENGES

Did you encounter any challenges or any benefits of working with people from different backgrounds and expertise? How did you bridge the language gap among different disciplines?

One thing to keep in mind: Writing styles between communities might differ. Be prepared to spend time discussing the use of different terminologies and clarifying different ideas and interpretations. Embrace the

[1]School of Mathematical Sciences, Queen Mary University of London, London E1 4NS, UK

[2]Faculty of Science and Technology, Norwegian University of Life Sciences, 1432 Ås, Norway

[3]School of Geography, Queen Mary University of London, Mile End Road, London E1 4NS, UK

[4]Flow Cytometry Science Technology Platform, The Francis Crick Institute, London, UK

[5]Alan Turing Institute, London NW1 2DB, UK

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use of new and previously un-explored tools, such as LaTex, when working with mathematical scientists (instead of Word), and make sure you can agree on a general writing style together.

FINAL THOUGHTS

What did you learn about interdisciplinary research from the project and what tips would you give to anyone considering undertaking such work?

This interdisciplinary work has been very inspiring and beneficial for all parties involved. It was truly inspiring to apply a theoretical framework to an important real-life application, working together across disciplines and together with Citizen Scientists. The whole communication, scientific work but also the writing went very smoothly, as everyone involved was very open for new perspectives and responsibilities were assigned clearly. We encourage other scientists to consider interdisciplinary projects, maybe at their home institution or outside.

It was truly inspiring to apply our theoretical framework to an important real-life application, working together across disciplines and together with Citizen Scientists.

From our experience, all sides can profit and the process can be very productive when responsibilities are set out early: Who will collect the data? Who will carry out the analysis and produce the figures? And who will contribute which section for the article? With these questions cleared up, it becomes much easier to tackle important problems.

In addition, working on the project has helped the team identify the need to develop visualization methods to communicate data and scientific findings effectively to the wider stakeholders involved; to provide mechanisms whereby research questions about the river environment can be co-created between scientists and society; and for the group to work on and discuss potential solutions to the environmental, and scientific, challenges together.

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