
First Rewilding Mathematics Seminar Brings Mathematicians and Ecologists Together

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In January, mathematicians and ecologists joined forces to launch a collaboration focused on the mathematics of Rewilding, a new and controversial approach to rebuilding ecosystems. Rewilding is a radical idea that differs from traditional ecological restoration in important ways. To understand the philosophy of Rewilding, we can turn to a metaphor offered by ecologist Johan du Toit. Suppose that you are the owner of a classic 1950s Chevrolet. At some point the car breaks down, and several parts need to be replaced. If you have the means and the resources, you could track down exactly the right replacement parts, manufactured for the original make and model of your car. This is analogous to traditional restoration: you've recreated a faithful replica of the original car. But what if the 1950s Chevrolet is your only car, and you're a taxi driver, and you have no way to get the original parts? You might replace the parts with whatever you have access to — parts of different cars, for example, or parts from other machines — as long as the parts work. You won't have an exact recreation of the original car, but you will have a functioning car. This is analogous to Rewilding: prioritising what is possible and what works, not bringing back the past.

In the changing climate and environment of the world today, ecological restoration can be impossible: some ecosystems simply can't exist in their former glory in current conditions. But Rewilding, as du Toit emphasised, is always possible, because its goal is to build ecosystems that flourish in the present. The word Rewilding is similar in meaning to "reorganising" or "rethinking" — the goal is to reimagine the wild, not to bring back the wild of the past.

The philosophy of Rewilding is designed to be practical and effective in the real world. But currently, there is no mathematical theory of Rewilding to help guide strategies, or to help measure and ensure effectiveness. In other areas of biology, including ecology, mathematics has made important contributions and helped to ground ideas in theory and evidence. The goal of the Rewilding Mathematics collaboration is to bring this power of mathematics to bear on Rewilding.

Introduction

The first seminar began with an introduction from Michael Singer, the lead organiser of the Rewilding Mathematics collaboration and a professor of mathematics at University College London. Singer is a pure mathematician, but when the International Centre for Mathematical Sciences (ICMS) launched the Mathematics for Humanity initiative, calling for projects that use mathematics to help solve problems facing humanity, he jumped at the opportunity to take action. Singer is a nature lover, and he wanted to do something to help with the biodiversity and climate crises. He had recently read about Rewilding, and "it caught [his] imagination." Because it doesn't yet have a mathematical theory, Rewilding turned out to be a perfect match for a mathematics collaboration. ICMS agreed, funding four seminars and a week-long workshop on Rewilding Mathematics. Researchers agreed, too: the first seminar drew over eighty participants, a range of ecologists and mathematicians all eager to join the project.

What is Rewilding?

After the introduction, Johan du Toit, Director of Science at the Institute of Zoology in London, kicked off the seminar with an overview of Rewilding. He traced the origins of the need for Rewilding to one of the major mass extinction events in recent history. In the Pleistocene era, beginning 2.5 million years ago until around twelve thousand years ago, large mammals like mastodons, giant ground sloths, and dire wolves stomped, grazed, and prowled over the Earth. Large mammals such as these play a crucial role in ecosystems: their presence affects plant growth, helps facilitate biodiversity, and opens new niches, among other things, all of which influences the environment around them. But most large mammal species are now extinct, and their loss has reverberated, changing the way that ecosystems behave.

These changes in ecosystems are visible today. In Africa, elephants eat shrubs, bark, and other wood like branches, which limits the range of trees in the savannah. But in the American West, which today has far fewer large mammals, "woody encroachment," or the spread of trees into grasslands, is a problem with serious ecological consequences. To combat woody encroachment, machines are sent in to remove the invading trees, essentially mimicking the role of elephants or other large herbivores in the ecosystem.

Machines vs. elephants, from Johan du Toit's slides. Elephant image from Stein Moe.

Rewilding hopes to use animals rather than machines or other human interventions to replace essential ecosystem functions. Much of Rewilding focuses on large mammals, under the theory that large mammals play an outsize role in shaping ecosystems. Rewilding aims to build ecosystems that are able to thrive, adapt, and sustain themselves long-term, even if those ecosystems are different from before or integrate new, "alien" plants and animals. An early experiment with this philosophy was in Oostvaardersplassen, a project in the Netherlands. Deer, horses, and cows were introduced to the area, which was once under the sea, to promote a healthy and functioning ecosystem. Today, Oostvaardersplassen is teeming with different birds, mammals, reptiles, and amphibians, and the land now encompasses wetlands, forest, and meadow. Introducing mammals helped to transform the ecosystem and rebuild biodiversity — even though horses and cows are domesticated animals not native to the area. They are like the spare parts from other machines used to make the classic Chevrolet run again.

The Mathematical Challenges of Rewilding

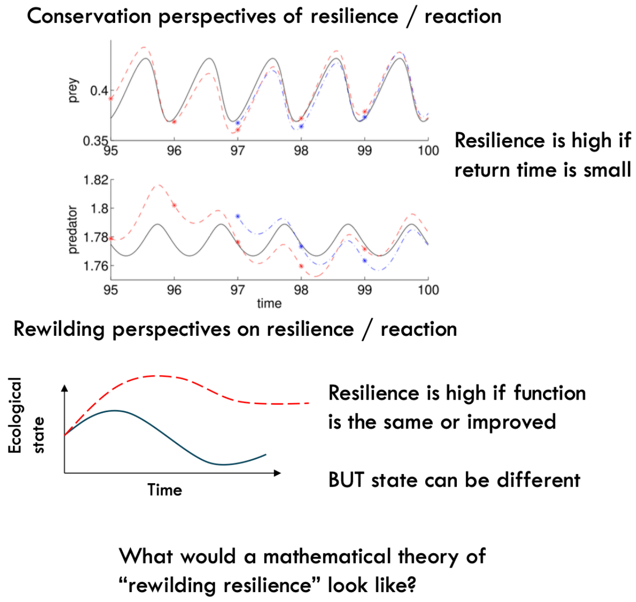
After the overview of Rewilding, Sergei Petrovskii, chair in applied mathematics at University of Leicester, Rachel McCrea, chair in statistics at Lancaster University, and Christina Cobbold, professor of mathematical biology at University of Glasgow, offered their first impressions of the mathematical problems posed by Rewilding.

The mathematical challenges broadly fall into two categories: prediction and evaluation. The prediction tasks involve predicting the impact of various interventions, so that potential options can be compared and the most promising ones chosen. Also relevant is understanding the current and likely future states of the land and climate in question. What is the probability that an ecosystem will soon undergo a major transition? What will the short- and long-term impacts be of introducing a particular animal or plant species to an ecosystem? How can we predict which animals are best suited to a given environment? One idea to approach this last question is to consider the "functional type" of animals: a profile consisting of their major features, such as their feeding habits and size. Ecosystems can then be studied for the distribution of functional types they support. For example, grassland savannahs support more grazing animals, whereas woodland savannahs support more animals that feed through a mix of grazing and eating woody plants.

The evaluation tasks, meanwhile, focus on how to judge the outcome of an intervention after it has been implemented. The mathematicians and ecologists suggested several potential goals for Rewilding projects: to increase the biodiversity of an ecosystem, maybe, or to increase its complexity or resilience.

In order to measure whether these goals have been achieved, they need to have mathematical definitions that properly express the ideas and philosophy behind the goals.

As Cobbold observed, there are already mathematical definitions of "resilience." For example, one definition states that the resilience of a system is the time it takes the system to return to its baseline state after a disturbance, where a quicker return to baseline indicates a more resilient system.


Conservation perspectives of resilience / reaction

Resilience is high if return time is small

Rewilding perspectives on resilience / reaction

Resilience is high if function is the same or improved

BUT state can be different

What would a mathematical theory of "rewilding resilience" look like?

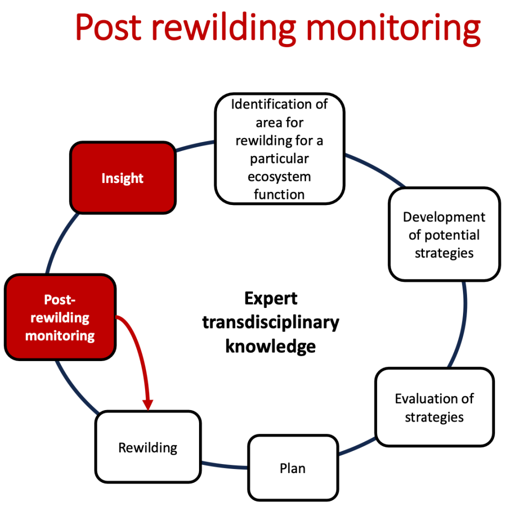
Mathematical perspectives on resilience, from Christina Cobbold's slides.

The objective of Rewilding, however, is not to preserve baseline states of ecosystems, but to ensure that ecosystems can adapt under pressure — even if they end up different from how they were before. This illustrates the importance of choosing the right definitions. Other definitions of resilience that focus more on the function rather than the composition of the system would be better aligned with the objective of Rewilding. What mathematical definitions of resilience best reflect the philosophy of Rewilding? Similar questions can be asked about other notions like the "complexity" of an ecosystem. Once these definitions are created, new questions emerge, such as: what kinds of data collection and monitoring are needed to gather enough information to feed into the new definitions?

Petrovskii noted that, while Rewilding poses unique questions, there are theories, models, and optimisation approaches in mathematical ecology that could potentially be used or adapted in the context of Rewilding.

Studying how the existing techniques can contribute to the new questions could be a promising starting point for research.

And McCrea emphasised the importance of rooting the math in the practice of Rewilding, saying "there's no point in developing cool statistical models if no one's going to use them." She outlined a research cycle where mathematics informs strategies and decisions in Rewilding projects, and then the outcomes of those projects inform the mathematics moving forward, with feedback flowing in both directions.



The Rewilding research cycle, from Rachel McCrea's slides.

Discussions and Suggestions

After the talks, the seminar opened for discussion. The drive to have a positive, real-world impact remained a motivating force throughout the seminar. For example, if a local government hopes to Rewild a degraded plot of land, Rewilding practitioners could recommend a specific intervention, offer a plan to monitor the land, and explain how to adjust the intervention based on the feedback from monitoring, with hard evidence to support each of these recommendations. Participants in the seminar recommended including policy experts in the process, to keep Rewilding scientists and real-world decision-makers on the same page. A suggestion to help make Rewilding projects accessible was to have short-term goals in addition to longer-term goals, which could be "wins along the way" for scientists and policy-makers alike to highlight and celebrate.

Rewilding aspires to foster complex ecosystems and biodiversity in all kinds of spaces, big and small, remote and urban. It welcomes interaction between humans and nature and hopes to bring wild spaces closer to humans. To that end, another goal from the discussion was to involve citizens and locals in Rewilding projects, so that people can be connected to and inspired by the Rewilding of places nearby.

The second Rewilding Mathematics seminar is in early March, when mathematicians and ecologists will convene once more and the discussion of Rewilding mathematics will continue. Stay tuned for another update!