A Participatory Complex Systems Modelling Approach Towards Rewilding in the UK

Imran Khan[1] and Christopher Sandom[2]

[1] School of Physics, Engineering, and Computer Science, University of Hertfordshire, Hatfield, UK, AL10 9AB
[2] School of Life Sciences, University of Sussex, Brighton, UK, BN1 9RH
i.khan9@herts.ac.uk

Introduction

The year 2021 marked the start of the United Nation's Decade of Ecosystem Restoration (Fischer et al., 2021). Nature recovery efforts aim to bring back the diversity of life to areas that have been degraded by humans: to change how people interact with the environment, and to allow more plants and animals to thrive alongside humans. For land owners/managers (i.e. those responsible for managing land resources), there is an increasing interest in adopting a more nature-friendly land management approach (Suding, 2011).

Numerous options to nature recovery exist, including "regenerative agriculture" (farming approaches that aim to have lower or net-positive environmental and social impacts) (Newton et al., 2020) to the more recent approach of "rewilding", which aims to *"restore self-sustaining and complex ecosystems with interlinked ecological processes that promote and support one another while gradually minimising human intervention"* (Perino et al., 2019). One approach to rewilding, called "trophic rewilding", looks to achieve this through the (re)introduction of missing "keystone" species: species that, despite having a low abundance, play a crucial role in improving ecosystem connectivity, increasing trophic complexity and biodiversity, and restoring the autonomy of natural processes (Perino et al., 2019).

For land managers and restoration professionals interested in rewilding, there remains uncertainty around the best-suited rewilding options for a particular ecological context. While practitioners are considering taking more data-driven decisions towards nature restoration, the underlying science for understanding precisely who the keystone species are, what populations are required, and what effects these changes may have on their wider ecosystem, remains difficult to access, understand and, therefore, apply.

Researchers and practitioners in Artificial Life (i.e. ALifers) are well-positioned to address this issue. While nature recovery is fundamentally a complex, ecological problem, (the science underpinning) rewilding efforts can be approached through the lens of complex systems modelling. The question of "What are the effects of species X on ecosystem Y given its properties Z?" can, with sufficient information about the constituent components, be modelled as a complex system. These modelling approaches can be coupled with local, expert ecosystem knowledge, to provide a starting point in tackling one of the "grand ecological challenges" of systems ecology (Martinez, 2020).

Current Work

We describe ongoing work where we look to approach this challenge. Working with ecologists and real-world stakeholders, we have (co-)developed an interactive tool to assist land managers or owners in their rewilding efforts: by helping them explore and engage with their rewilding options and opportunities, as well as to understand some of the potential effects that the (re)introducion of (several) species may have on their local ecosystem.

Taking a participatory approach towards the development of this tool through regular stakeholder engagement and participatory workshops, we place real-world stakeholders and local community experts at the heart of our approach. As part of this project, we aim to address issues around the accessibility of underlying science, the competency in engaging with, and interpreting, complex systems models and to improve the autonomy of end-users for making data-driven decisions when approaching ecological problems.

Our intention is **not**, however, to develop a strictly prescriptive or predictive tool. Moving from the *"myth of the technological fix"* (Oelschlaeger, 1979), the tool aims to complement, not replace, the knowledge of real-world stakeholders—local ecologists, restoration experts, and land owners—by synthesising knowledge from on-the-ground experts with ALife-inspired modelling approaches, in an attempt to improve ecosystem recovery efforts.

Tool Development though Participatory Modelling and Design

Through a series of workshops and ongoing engagement between January-March 2022 with stakeholders—who include experts in conservation ecology and nature restoration (via Rewilding Britain Network, who work closely with land managers in the UK)—we identified three core requirements that the proposed tool sought to meet. Specifically, these stakeholders need a solution to help them understand: (1) which species might be suitable for (re)introduction given the properties (size, net primary productivity, vegetation type) of their land, (2) the possible and appropriate population densities for each available species, and (3) the possible resultant interactions between species and on the wider ecosystem resulting from (re)introducing (several) species. These form the starting point of the tool development, which can be broken down into two distinct, (concurrently-developed) parts: the construction of the complex system (i.e. the underlying mathematical models), and the user interface, to provide stakeholders with the ability to interact directly with the model to run their own simulations, and to provide comprehensible outputs of the results.

The system was modelled through collaborative efforts with one key stakeholder—a restoration ecologist (CS) working as an advisor to land managers in the UK—who also provided access to the necessary data to construct the model. Properties of system components (i.e., different carnivore and herbivore species) were modelled using a range of existing datasets (Middleton et al., 2021; Lundgren et al., 2021; Kissling et al., 2014; Sandom et al., 2017; Faurby et al., 2018; Santini et al., 2018; Middleton, 2021) which included data related to a species' dietary requirements, its natural density distributions, and physiological data (e.g. mass, metabolic rates). Additional datasets related to habitat suitability and additional dietary preferences of species, were compiled in collaboration with CS. Interactions between system components (such as how herbivore traits affect different types of vegetation) were derived through relevant ecological literature (Carbone and Gittleman, 2002), and constructed as mathematical models between system components. Regular evaluations of the system was performed by CS, with the intention of both enhancing the stakeholders' understanding of the underlying system to improve the confidence in its final results (Penn et al., 2013), but also to identify (and rectify) any (potential) erroneous modelling that may have occurred.

Similarly, the (co-)design of the user interface as well as the outputs of the simulation were developed through a combination of previously-established user requirements (provided by CS), as well as engagement with end-users/stakeholders during workshops: with further feedback provided by an expert in human-computer interaction and participatory design. Taking feedback from these workshops, the user interface underwent numerous iterations, with respect to both design and usability, as the complexity of the tool evolved. Involving key stakeholders throughout the course of the interface development ensures that those issues related to accessibility and comprehension of the underlying data are addressed, allowing these end-users to derive the intended value from the tool. A prototype of this tool is available at rewildingdemo.imytk.co.uk.

Concluding Remarks

The UN's Decade of Ecosystem Restoration has reignited nature recovery efforts, with rewilding efforts being considered as an option towards driving desirable outcomes for ecosystems. While the science of nature restoration is slowly improving, it still remains difficult to access and understand for practitioners. Ecosystems are remarkably complex. These complexities and uncertainties around the longer-term outcomes of rewilding interventions may make it difficult for restoration experts to fully realise and explore their options based (solely) on their expert knowledge.

The nature of such a complex (dynamical) system makes it near-impossible to construct a complete model that accurately accounts for all of its components and interactions. These incomplete systems may give rise to potentially-attractive phenomena for ALifers, such as chaos or emergence. However, it is these same, inexplicable outcomes that may cause some end-users (particularly those engaging with real-world problems and whose decisions have significant ecological and financial consequences) to approach these models with caution, or may hinder their buy-in altogether. Central to our approach, therefore, is ensuring that the expert knowledge provided by stakeholders remains a key component in the development of the model. At the same time, we maintain transparency of the (current) incompleteness of our system, instead allowing end-user expertise to complement, and even supersede, its recommendations.

Our present approach does not aim to be *prescriptive* in its recommendations, nor does it currently attempt to *predict* the long-term ecological effects of rewilding interventions. Rather, it provides a snapshot in time: immediate insights into "what if?" questions which, when coupled with the contextual knowledge of a local ecosystem, can empower real-world stakeholders to make data-driven decisions, by being able to use data and knowledge that has previously been inaccessible to them. In this way, ALifers are able to lend their "ALife tools"—those that have allowed us to instantiate our own thought experiments—to other disciplines and beyond.

Far from providing technological solutions to socio-ecological problems, ALifers interested in tackling these issues may instead benefit through collaborative efforts and participatory approaches with other disciplines and real-world stakeholders. With due consideration for the expertise provided by both academic and non-academic experts in other fields: as we demonstrate, ALifers may be able to bridge the gap for real-world stakeholders into better accessing, understanding, and engaging with the underlying science that may facilitate action. Our ALife-inspired methods and perspectives, then, can be used as a catalyst in finding solutions for some of the grand societal and ecological challenges that concern us at this present moment.

Acknowledgements

This work was funded by the Natural Environment Research Council (NERC) Discipline Hopping Grant through the University of Sussex, UK.

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