Models as games: a novel approach for ‘gamesourcing’ parameter data and communicating complex models

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# Summary

# Introduction

In recent years, the use and application of models has become widespread and indispensable in conservation science, ranging from demonstrating the likely effects of climate change (IPCC 2021) to supporting the understanding of fundamental processes in natural resource management (e.g. Fryxell et al. 2010; Cusack et al. 2020). Given the continued rapid global loss of biodiversity (Ceballos et al. 2015; Ceballos, Ehrlich, and Dirzo 2017), understanding the mechanisms and consequences of such loss is vital. Although a number of drivers of biodiversity loss have been identified (e.g. Maxwell et al. 2016), one of the most prevalent and widespread ones is human exploitation of habitats and natural resources, both directly (e.g. through hunting or habitat loss to agriculture) or indirectly (e.g. through international trade in natural resources) (e.g. Wilting et al. 2017). Because resource use is fundamentally driven by economic and social processes, it has long been recognised that accurate predictions thereof is reliant as much on understanding resource dynamics as it is on understanding human behaviour and decision-making (Milner-Gulland 2012; Schlüter et al. 2012). Thus, the development of socio-ecological models in which natural resource dynamics and human decision making interact is becoming increasingly urgent.

Cutting-edge modelling approaches have made significant progress towards this goal. For example, Orach, Duit, and Schlüter (2020) used an agent-based model to show how coalitions of interest groups can stabilise natural resource dynamics, whereas Cusack et al. (2020) used a novel agent-based modelling framework (Duthie et al. 2018) to assess the effect of lobbying on species extinction risk. Although such modelling efforts represent significant progress in modelling complex socio-ecological systems, their increased complexity poses to two, interlinked, challenges. First, models are often difficult to communicate clearly to non-specialist audiences in the first place [**REF?**], and this challenge increases with model complexity. This is particularly important for models for resource use in socio-ecological systems, as they are often specifically intended for use by managers or stakeholders who may lack technical expertise. Much has been said about improving the uptake of models in such settings (e.g. Addison et al. 2013; Schuwirth et al. 2019; Will et al. 2021), and detailed documentation of the purpose, organisation and predictions has been highlighted as particularly important (Grimm et al. 2020). Even so, often the evidence for practical uptake of many models is limited (Addison et al. 2013; Zasada et al. 2017). Second, their complexity implies the need for extensive data to parameterise them effectively. In terms of socio-ecological systems, while data to parameterise the ecological component are often relatively easily available, the human decision-making components are often based on limited theory and lack a general empirical basis (Groeneveld et al. 2017). Not only may this lead to limited predictive power, a perceived lack of empirical basis may negatively affect their acceptance by stakeholders (cf. model “quality” as in Kolkman et al. 2016). To maximise the adoption of complex socio-ecological models as management tools, both appropriate representation of human decision-making and effective communication are therefore key.

Games have a long history of being used as research tools, particularly for aiding the communication of complex ideas and processes to non-specialists, and increasing stakeholder engagement. [**For example, XXX , XXX, XXX**]. Given this long history, it is striking that the parallels between games (particularly videogames) and models are not discussed more widely. All models are abstract representations of environments, actors and relationships, with inputs (parameters) and outputs (predictions or inferences). Similarly, all games present a player with an environment in a given state (parameters), including one or more actors, which can take actions (inputs) to affect the environment for a given effect (outputs). It is worth stressing that every game has an underlying model that defines the state of the environment, relationships between objects in this environment, and inputs and outputs available to the player. However, while games are by definition designed with player (user) interaction in mind, models rarely have user-facing or even user-friendly interfaces, and running or adapting them to specific circumstances usually relies on technical expertise. Casting models as games provides an opportunity to effectively improve the communication and understandability of even relatively complex models. Inputs and outputs may be presented in a visual way and tweaked depending on the type of audience, and both potential applications and limitations of the model can be demonstrated effectively.

In addition, presenting a model as a game provides an opportunity to empirically collect data on how stakeholders make decisions in the modelled environment. Games have already been widely used for data collection to answer specific questions (e.g. Meinzen-Dick et al. 2016; Villamor and Badmos 2016; S. Rakotonarivo et al. 2021; O. S. Rakotonarivo et al. 2021) on what affects decision-making in socio-ecological systems. A less well-explored potential of using this approach is using in-game decisions directly as a “big data” source to improve the parameterisation of the underlying model itself. Many existing models represent human decision-making by relatively crude algorithms (e.g. fully rational utility maximisation) despite widespread recognition that this does not reflects real-world decision-making (Groeneveld et al. 2017). By presenting real-world stakeholders with in-game decisions that would otherwise be taken by a predefined algorithm, large data sets of actions and outcomes may be collected. Given a large enough sample of players and in-game conditions, such data might then be used to train decision-making algorithms that better reflect human decision-making in natural resource management. It is notable that this “gamesourcing” or “Gamorithm” Sipper and Moore (2020) approach has already been used in a number of other fields (e.g. crowdsourcing accurate protein-structure models (Khatib et al. 2011) and classification of fluorescence microscopy images (Sullivan et al. 2018)) but not yet in conservation science. Thus, model-games can be considered “virtual laboratories” (Duthie et al. 2021) to not only test specific hypotheses or predictions, but potentially also as an effective method to source data to parameterise the underlying models, based on in-game decisions by real humans.

We here aim to illustrate the potential for this model-game approach, both in terms of aiding model communication as well data collection for improved parameterisation, by introducing Animal&Farm (A&F). We developed A&F as a simple interactive game front-end for a complex socio-ecological modelling framework (GMSE), in which the player acts as the manager of a virtual environment in which a population of wild grazing animals (the natural resource) may adversely affect farming yield, with farmers acting to maximise their yield and potentially hunting the animals. We argue that that by acting as an interface between users (i.e. players) and a complex underlying model with many components and assumptions, such a game can simultaneously (1) aid the communication and useability of the underlying model and (2) can be used to gather data to improve the parameterisation of such models. We first briefly summarise the underlying modelling framework, its potential and limitations. Second, we describe both the structure of A&F itself as well as its database back-end. Third, we outline how this approach may be used to collect data on player decision-making in simulated *in silico* experiments, and present some example results of doing so; noting that these findings are intended as illustrative only. Finally, using test player feedback as a basis, we discuss both the limitations of this approach as well as its wider potential.

# Outline of approach

## Underlying model: GMSE

### Basic introduction of GMSE principles and structures

### Brief discussion of limitations of GMSE

## Animal&Farm

### Structure as relating to GMSE

### Database “back end”

### “Sandbox” for *in silico* experiments

Expandability of parameter variation

Setting up “scenarios” to test specific hypotheses/predictions

# Example application

## Methods/rationale for scenario set up

## Illustrative results

## Summary of player feedback

# Discussion

## Brief summary of aims, process and outcome of example scenarios

## Revisit player feedback

## Discussion of limitations of overall approach, with reference to player feedback

## (Potentially general discussion of issues with games approach?)

## Discussion of potential

### Communication/education: highlight player feedback as very point of approach: game may be abstract, restrictive and not representative of reality, but this is case for any model, yet latter point often “hidden.” By taking game approach, shortcomings more obvious to non-specialists.

### Yes, problematic when expecting direct application to real life, but again this is/should be clear for all models.

### Highlight expandability of approach, sandboxing ideas in flexible simulated environment

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