Proposal title:
Approximate Bayesian Computation (ABC) for calibrating and evaluating Individual Based Models

Supervisors:
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Background:
Individual-based models (IBMs) are used to simulate the actions of individual animals as they interact with one another and the landscape in which they live. When used in spatially-explicit landscapes IBMs can show how populations change over time in response to management actions. For instance, IBMs are being used to design strategies of conservation and of the exploitation of fisheries, and for assessing the effects on populations of major construction projects and of novel agricultural chemicals.
There is urgent need to improve methods of calibrating such models: existing methods are too slow, and not always accurate. This project aims to improve the best existing method: Approximate Bayesian Computation, ABC. ABC is currently being used for statistical inference in a diverse range of applications in ecology, evolution and more widely, including for example: models of elephants in Amboseli; mackerel in the North East Atlantic; local butterfly populations; but also evolution of pathogens; social network analysis; and statistical physics. In most of these cases the challenges of parameter estimation and model comparison are both of importance, but implementation can prove computationally expensive. This project aims to improve ABC methods and to collaborate with model builders to help them in fitting models to data. Initial focus will be on IBMs developed for fisheries management by CEFAS, part of the UK government, https://www.cefas.co.uk/.

Project description:
ABC compares model outputs with data and is particularly useful for statistical inference where the model is only available as a computer simulator such as an IBM. There are many open problems in ABC, some of which lie at the heart of this project, including:

- ABC for high-dimensional parameter spaces. IBMs often have more than 10 parameters that have to be estimated by fitting the model to data: more than in many current applications of ABC.
- ABC for computationally expensive simulators. Some IBMs take several minutes to complete a run. This is a problem because existing ABC methods require thousands of runs to obtain reliable results.

This project will develop new methods to address these issues, driven by the need for accurate fisheries models to guide fisheries management.

Initial work will be to gain familiarity with models and methods to be used in the project. The MSc task will be to perform initial work on calibrating an IBM for sea bass using existing approaches, paying particular attention to the deficiencies of these approaches. The deliverables are the software that performs this calibration, and a write-up that compares the different approaches, and details the innovations that were required in order to achieve the end results.

In the PhD project that follows, there are three important areas in which new methods must be developed for calibrating IBMs. The main focus is on the following three areas:

- **Expensive simulators.** Develop methods that are computationally feasible despite the use of an IBM that takes a long time to simulate.
- **High dimensional ABC.** Investigate the accuracy of existing approaches to high dimensional ABC, developing improvements where necessary, particularly to enable model comparison.
- **Estimating model error.** To develop methods for estimating statistical models for the error in IBM models; to gain an understanding of this error, and thereby to improve the accuracy with which models are fitted to data.

In the initial project, the student will choose to focus on making developments in one of these areas.